RESOURCE and POTENTIAL RECLAMATION EVALUATION

HORSE NOSE BUTTE STUDY AREA -DUNN CENTER LIGNITE FIELD

EMRIA REPORT #9 1977

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF LAND MANAGEMENT
BUREAU OF RECLAMATION
GEOLOGICAL SURVEY

EMRIA

(Energy Mineral Rehabilitation Inventory and Analyses)

EMRIA is a coordinated approach to field data collection, analyses, and interpretation of overburden (soil and bedrock), water, vegetation, and energy resource data. The main objective of the effort is to assure adequate baseline data for choosing reclamation goals and establishment of lease stipulations through site-specific preplanning for surface mining and reclamation.

These reports are prepared through the efforts of the Department of the Interior, principally by the Bureau of Land Management, Bureau of Reclamation, and Geological Survey. Assistance is also provided by other Federal and State agencies.

Reports under this effort are:

EMRIA Report	Location
1	Otter Creek, Montana
2	Hanna Basin, Wyoming
3	Taylor Creek, Colorado
4	Alton, Utah
5	Bisti West, New Mexico
6	Foidel Creek, Colorado
7	Red Rim, Wyoming
8	Bear Creek, Montana
9	Horse Nose Butte, North Dakota

Published November 1977

HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

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RESOURCE AND POTENTIAL RECLAMATION EVALUATION

OF

HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

INTRODUCTION

A growing and affluent society is creating an ever increasing need for energy. Attention has focused on the coal resources existent in the Western States, primarily the Rocky Mountain and the Northern Great Plains regions, due to the abundance, ease of extraction, and the quality of the coal present. It is the responsibility of the Bureau of Land Management to assist in meeting these energy demands and, at the same time, provide sound reclamation and rehabilitative guidelines so that the lands subjected to disturbance are returned to a useful condition.

Purpose

The purpose of this study is to assure adequate baseline data for choosing optimum reclamation objectives and for establishing appropriate data and interpretation for preparation of lease stipulations for the Horse Nose Butte Study Area.

Objectives

a. To analyze and quantify environmental impacts from surface mining of coal.

b. To provide resource and impact information to the leasing site selection procedures as set forth by the Secretary of the Interior.

c. To provide environmental resource information needed to implement effective reclamation programs and for the development of meaningful lease stipulations as required.

d. To provide resource and impact information to support State and local land use planning efforts.

e. To determine the present and potential capability of the soil and bedrock to support and maintain vegetation on known coal deposits.

f. To provide physical and chemical data from which realistic stipulations may be prepared for exploration, mining, and reclamation plans.

g. To provide data needed in the preparation of Environmental Impact Statements, Environmental Analysis Records, and to aid in the review of mining and reclamation plans for proposed land disturbing activities in the vicinity of the area.

Authority

Public Land Administration Act of July 14, 1960 (74 Stat. 506).

Responsibility

Bureau of Land Management

a. Select reclamation study areas for coordinated investigation of vegetation, soil, geological structure, surface water, and ground water.

b. Acts as Contracting Officer in the coordination, establishment, and execution of work orders.

c. Reviews and consolidates work order and field office data.

d. Procurement of easements and rights-of-way to conduct the studies.

e. Distributes technical data, reports, and reclamation and rehabilitation recommendations to Bureau of Land Management field offices.

Bureau of Reclamation

a. Conducts a land classification for determining suitability of bedrock material for use in revegetation of shaped spoils.

b. Conducts drilling operations for the procurement of core samples for coal and soil analyses.

c. Installs casing in holes selected for ground-water observation wells.

d. Characterizes and interprets suitability of overburden materials as well as substrata immediately below the coal resources for purposes of revegetation.

e. Arranges for greenhouse studies for determining overburden materials potential for supporting vegetative growth.

f. Conducts mechanical weathering tests of core samples to determine stability of overburden materials.

g. Recommends to district office, Bureau of Land Management, suitable plant species for use in areas to be reclaimed.

h. Advises district office, Bureau of Land Management, on reclamation techniques.

i. Prepares geologic maps, logs and cross sections.

j. Advises the Bureau of Land Management on significant paleontological sites in the study area.

Geological Survey

a. Conducts vegetation and soil studies which will result in vegetation maps and related soil characteristics.

b. Assesses reclamation potential based on water available from precipitation, the effects of surface mining on area hydrology, and the measures required to prevent adverse effects on surface and ground waters of the area.

c. Prepares sediment yield maps.

d. Prepares erodibility maps.

e. Estimates annual runoff and peak flows.

f. Collection and interpretation of data to predict alternative solutions to ground-water problems encountered during mining and reclamation.

g. Implementation of a monitoring system to define baseline conditions and to document ground-water changes in flow and quality caused by mining and reclamation.

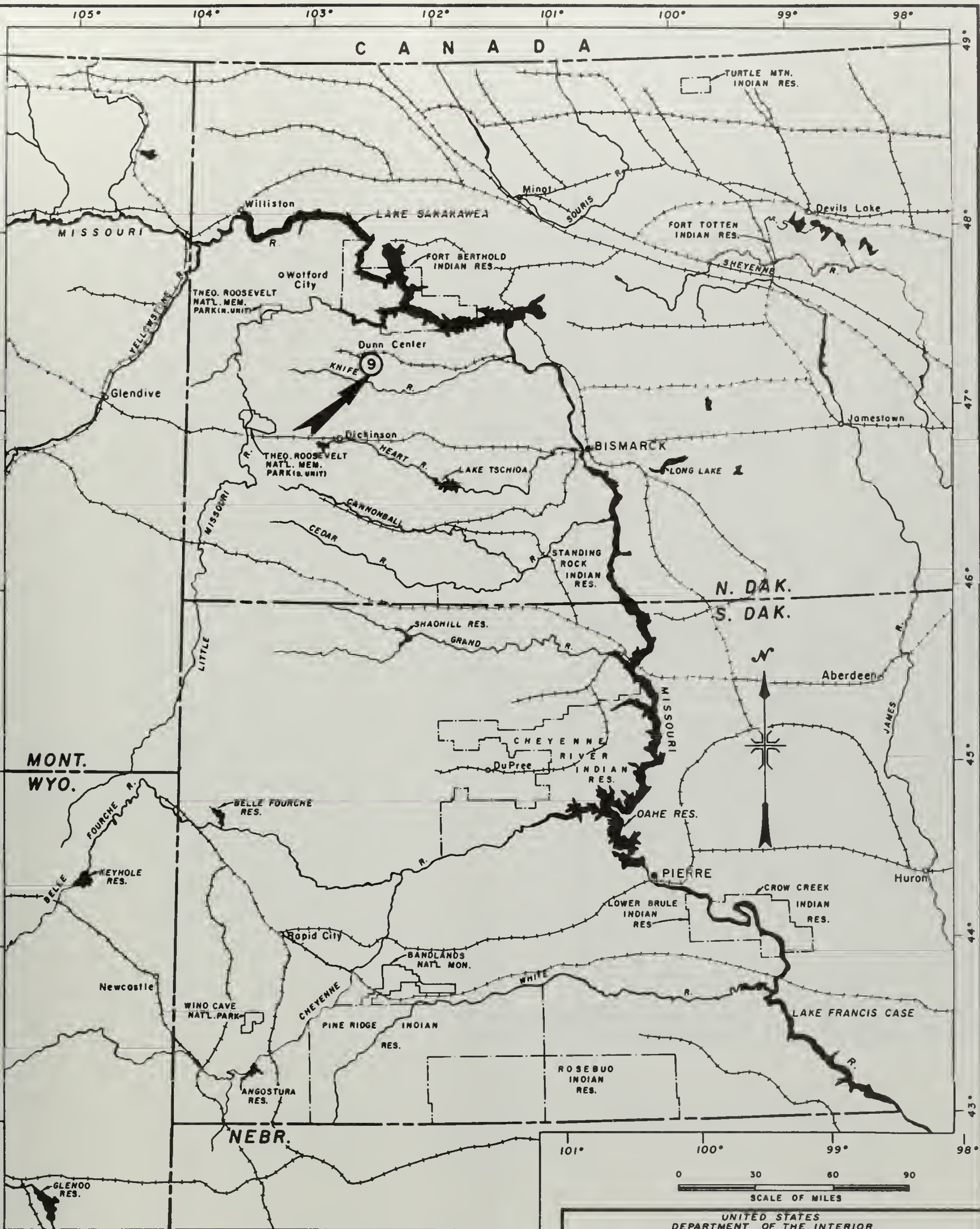
h. Prepares ground-water maps.

i. Tabulation of coal resources estimates.

j. Table of analytical results on coal resources.

General Description

The Horse Nose Butte Study Area is located in west-central North Dakota in Dunn County, approximately 4 miles southeast of Dunn Center. Plate 1 shows the general location. The area includes about 2,560 acres in all or parts of Sections 3, 10, 11, 12, 14, and 15, T. 144 N., R. 94 W. Photograph 1 and Plate 2 show the area setting and topography. All surface is privately owned. Most minerals, including coal, are federally owned as shown on Plate 3.



(9) HORSE NOSE BUTTE STUDY AREA—EMRIA NO. 9

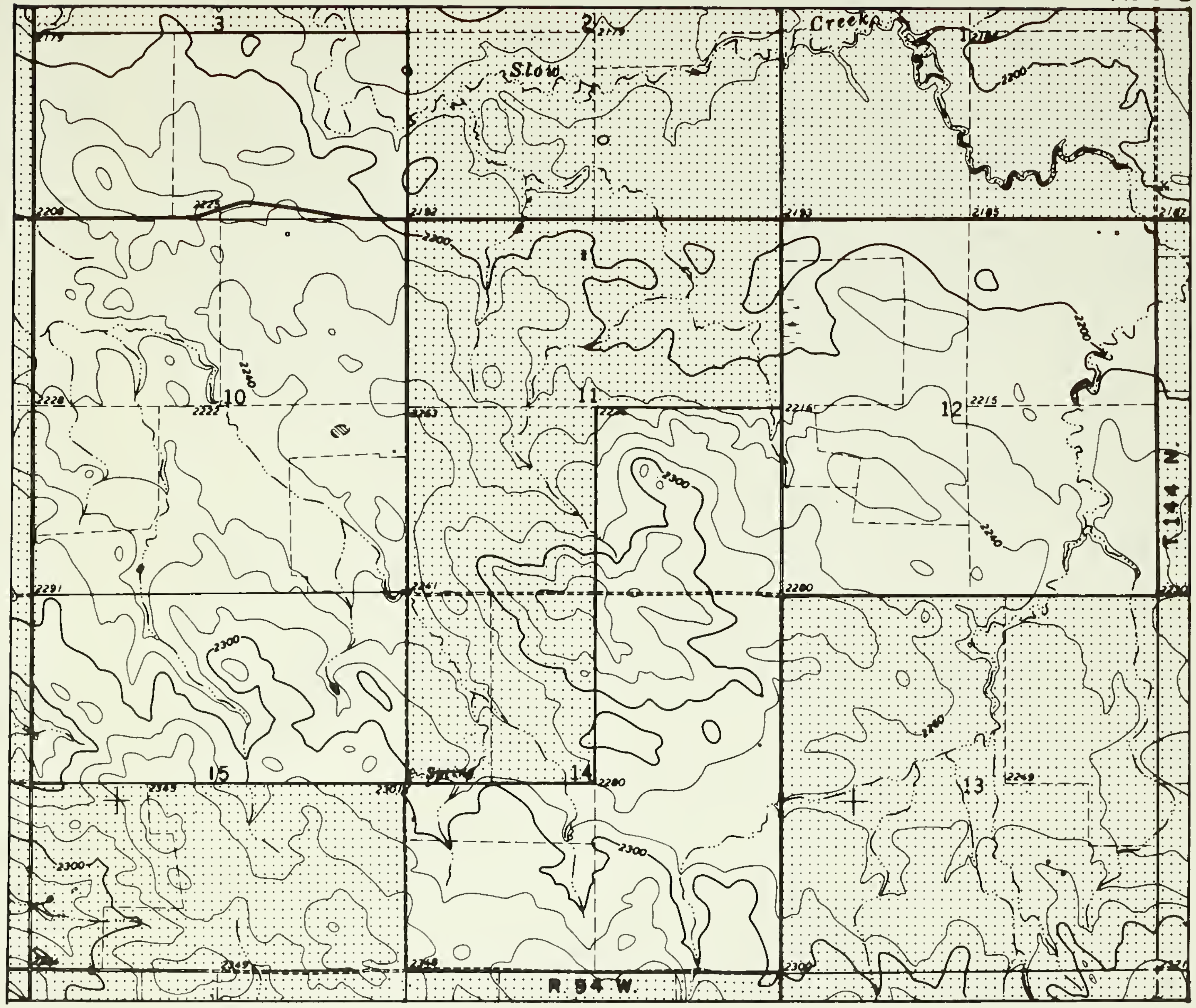
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION

EMRIA STUDY AREAS
NORTH DAKOTA, SOUTH DAKOTA, MONTANA & WYOMING

GENERAL LOCATION MAP

DESIGNED V. LINSSEN SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
CHECKED G. J. T. APPROVED

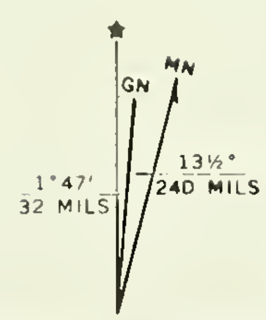
BILLINGS, MONTANA MARCH 1976 | 1305-600-77



1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

NOTE: STUDY AREA NOT STIPPLED

CONTOUR INTERVAL 20 FEET



UTM GRID AND 1973 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

QUADRANGLE LOCATION

PORTION OF U.S.G.S. DUNN CENTER QUADRANGLE

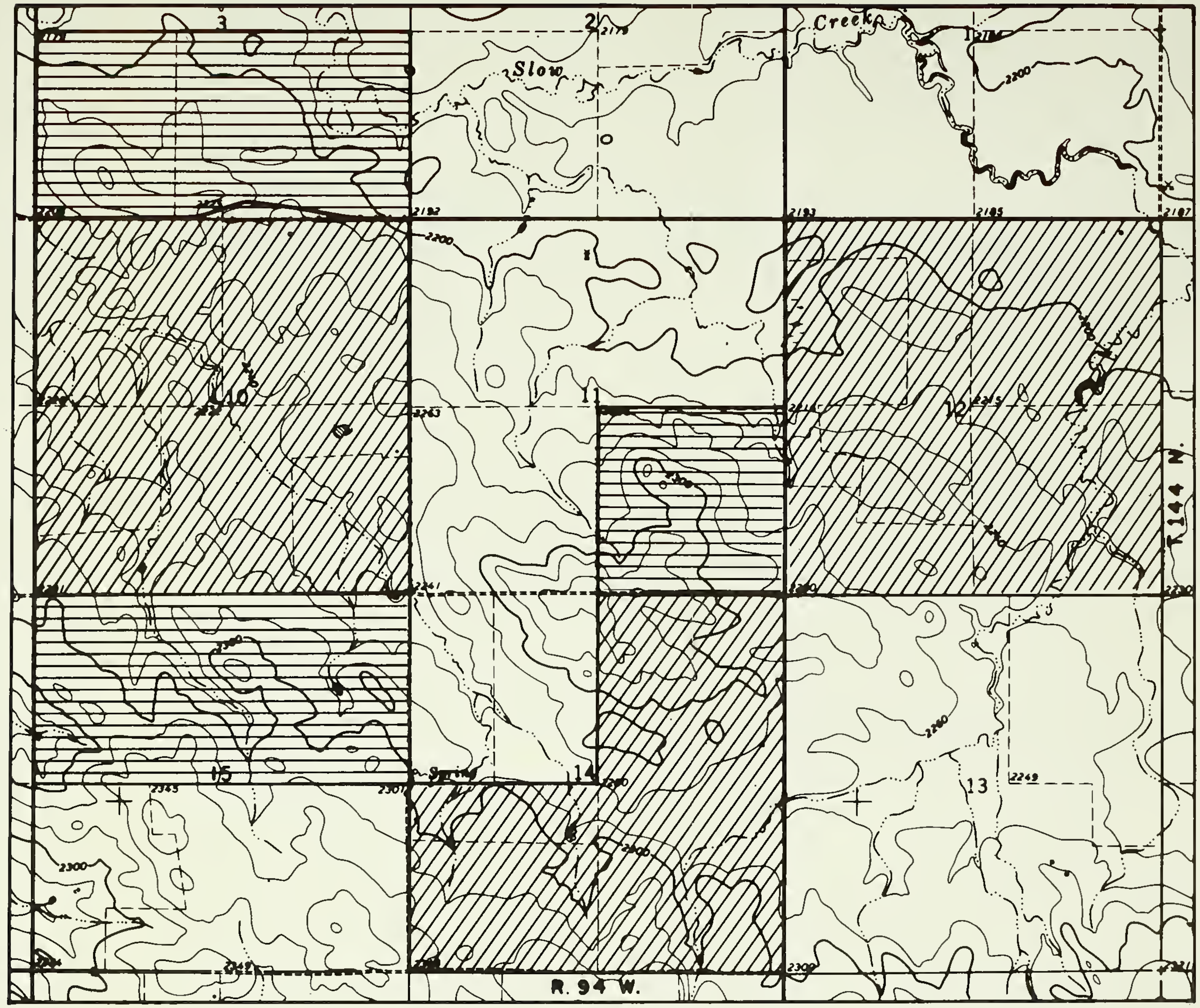
RESOURCE & POTENTIAL RECLAMATION EVALUATION

HORSE NOSE BUTTE STUDY AREA

DUNN CENTER LIGNITE FIELD

TOPOGRAPHY

Plate 3



MINERALS OWNED BY THE FEDERAL GOVERNMENT

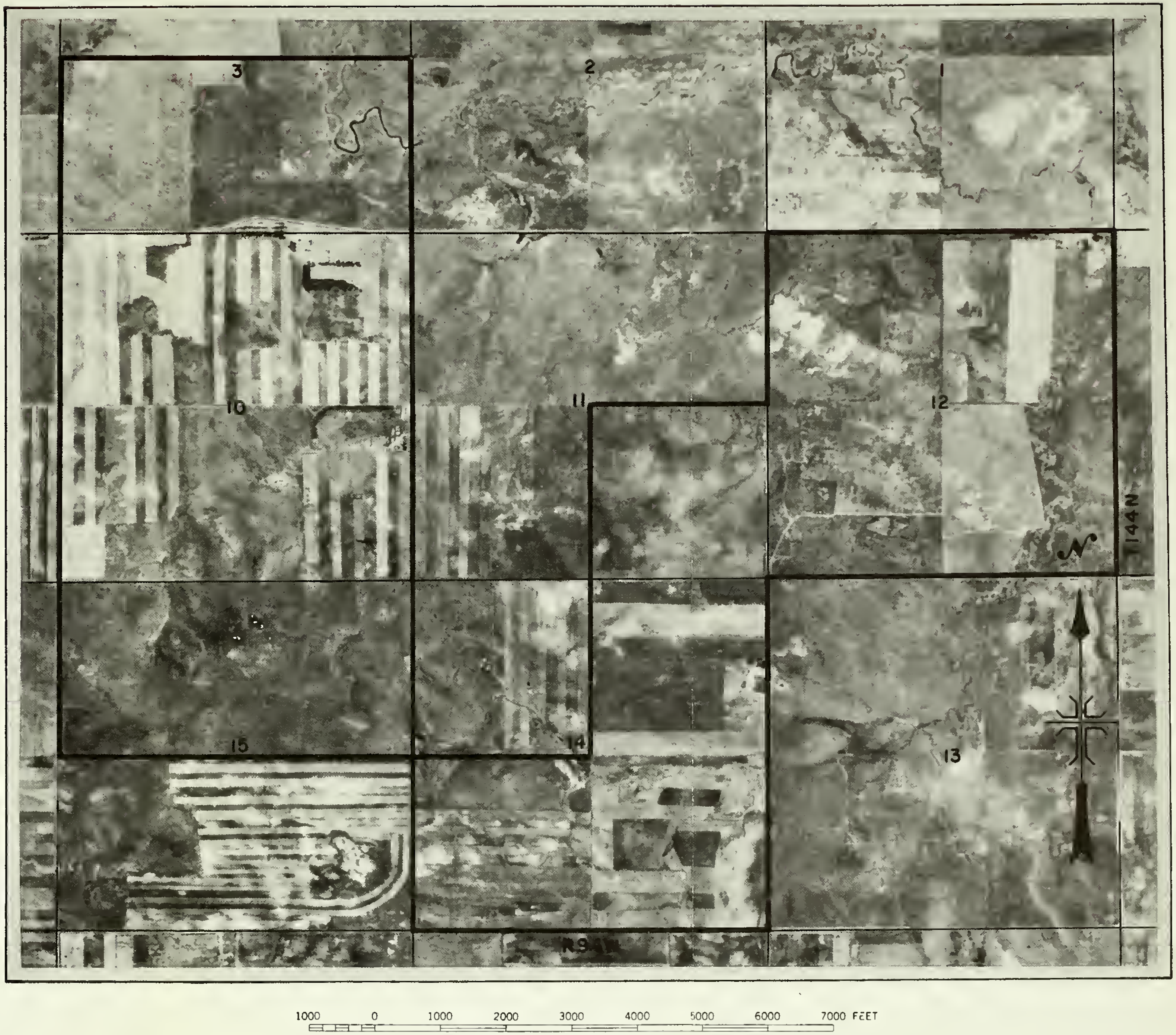
ALL MINERALS (ACQUIRED)

COAL ONLY

ALL SURFACE PRIVATELY OWNED

RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

MINERAL STATUS MAP



Photograph 1 - Aerial view of the Horse Nose Butte Study Area. This photograph is a portion of the Bureau of Land Management Photograph MDAD 9-33-93 (8/18/75).

CLIMATE

General

The Horse Nose Butte Study Area has a continental-type climate characterized by cold winters and warm summers. Climatic conditions should be similar to that recorded at the Dunn Center weather station, located about 4 miles northwest of the area.

Sunshine can be expected on 60 percent of the days during the year with July being the sunniest month (75 percent of days having sunshine). November and December are the cloudiest months with about 50 percent of the days having sunshine.

Windstorms occur frequently with velocities generally being highest during the winter and early spring months. In 1975, some buildings were dismantled by high winds in the area; however, storms of this severity are rare. The prevailing wind direction is from the west-northwest except during May through August when the prevailing winds are more from the east. Thunderstorms are reported in the general area 30 to 35 days each year and may be accompanied by hail. Hail is very sporadic, occurring two or three times each year within the county.

Temperature

Temperatures recorded at Dunn Center range from a maximum of 111°F. to a minimum of 52°F. below zero. The average annual recorded temperature is 40.3°F. Monthly average temperatures for the Dunn Center weather station recorded between 1918 and 1974 are tabulated below:

Jan.	9.6°F.	May	52.7°F.	Sep.	55.6°F.
Feb.	14.7	June	62.1	Oct.	43.4
Mar.	25.2	July	68.9	Nov.	28.3
Apr.	40.6	Aug.	66.9	Dec.	16.1

Frost penetrates to a depth of 3 to 5 feet during the approximate 121-day freezing period.

The beginning and ending dates of the frost-free period and the growing season for hardy crops were compiled from the Dunn Center station. These data and related information are shown in the following tabulation:

Temp.	Average Dates Last in Spring		First in Fall	Average Days Between	Remarks
32°	May 18	to	Sept. 15	121	50-year record
28°	May 8	to	Sept. 28	144	26-year record

Table 1 shows the potential consumptive use of moisture by plants during the frost-free period.

Precipitation

The average annual precipitation at Dunn Center is 16.31 inches. The mean annual precipitation within a 40-mile radius of the area is 16.05 inches. Figure 1 shows the location of weather stations and the deviation from the average. The recorded annual precipitation ranges from a low of 7.17 inches in 1936 to a high of 26.02 inches in 1903. The average monthly precipitation recorded at the Dunn Center station for the period 1918 to 1974 are tabulated below:

Jan.	0.41 in.	May	2.21 in.	Sep.	1.45 in.
Feb.	0.42	June	3.72	Oct.	0.90
Mar.	0.61	July	2.35	Nov.	0.59
Apr.	1.47	Aug.	1.79	Dec.	0.39

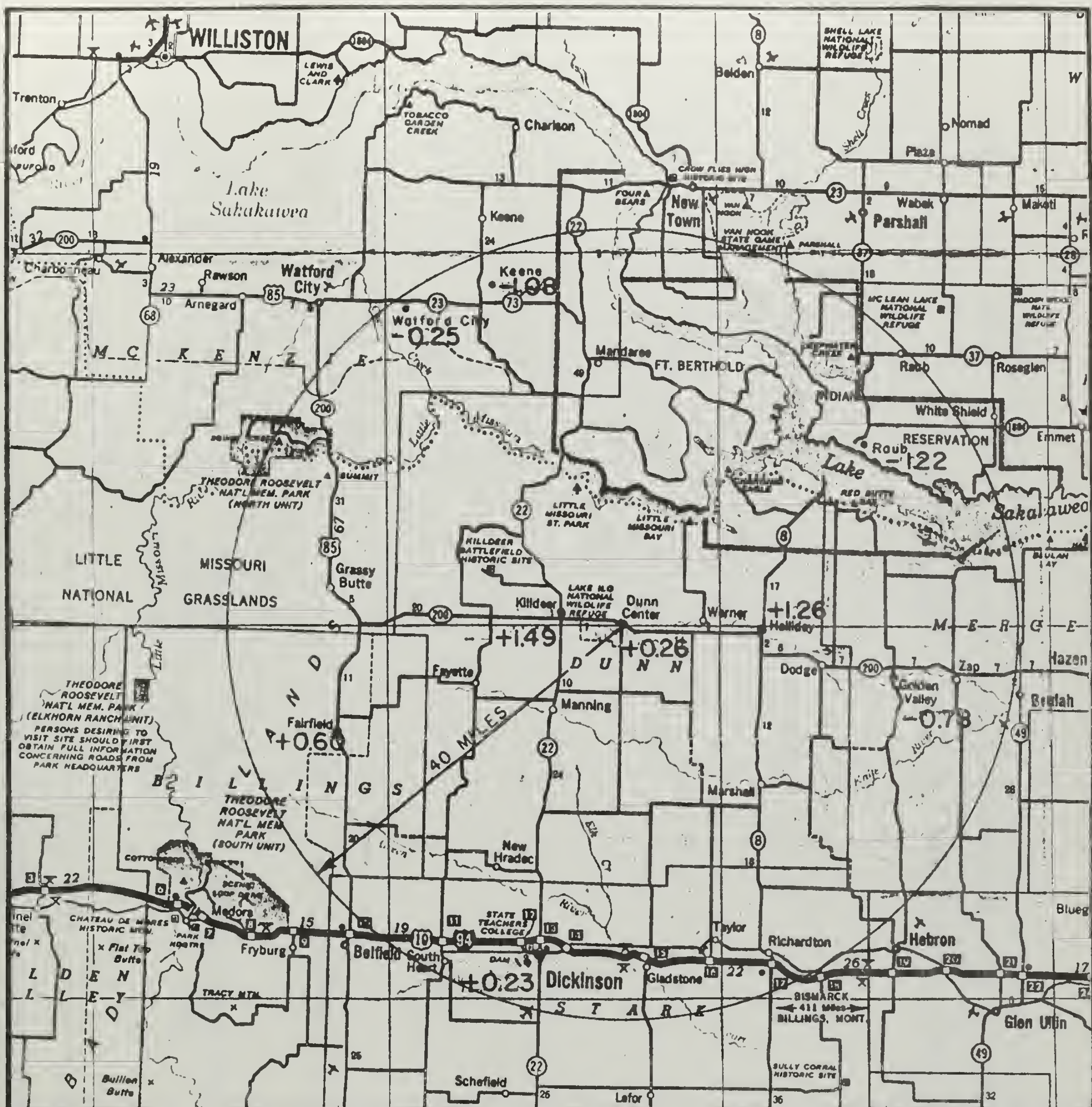
Over 75 percent of the annual precipitation falls during the April through September period.

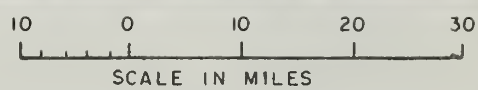
The amount of snow received annually is about 30 inches. Measurable amounts of snow can be expected from October through April. Snow (2- to 6-inch depths) covers the ground about 85 days each year, mostly during the months of December and January. High-velocity winds, during the winter, pile snow in drifts several feet high in protected areas. Unprotected areas can be completely stripped of snow. Fluctuating temperatures above freezing will usually remove the snow cover for a period of days during the winter months.

Effects of Climate on Revegetation

Climatic differences within the area are small. However, moisture and frost conditions of the soil can locally be affected by exposure to wind and sunlight. These micro-climatic differences would be altered by changing the topographic surface during reclamation.

The precipitation received during the growing season of 121 days is adequate for revegetation with native grasses and small grains. However, potential consumptive use of water by plants during this





NOTE

The 40-mile circle around the Horse Nose Butte Study Area includes an area in which average yearly precipitation is about 16.05 inches. Minus or plus (inside circle) indicates deviation from 16.05-inch normal at selected stations.

PRECIPITATION DEVIATION AT SELECTED LOCATIONS NEAR THE HORSE NOSE BUTTE STUDY AREA

Table 1 - Potential Consumptive Use of Moisture and Available Moisture - Native Grasses 1/

Horse Nose Butte Study Area - Dunn Center Station

Month	Midpoint	Accumulative Days to Midpoint	Mean Air Temp. ($^{o}F.$)	Monthly Requirement Inches	Moisture Reserve Inches	Precipitation Inches	Difference Inches 3/
May 10					+3.62 2/		
	May 20	11	58.4	2.72		2.51	+3.41
June					+3.41		
	June 15	37	61.1	4.41		4.01	+3.01
July					+3.01		
	July 15	67	68.5	5.87		2.29	-.57 4/
August					-.57		
	August 15	98	67.5	5.17		1.86	-3.88
Sept.					-3.88		
	Sept. 12	126	65.2	3.54		1.37	-6.05
Sept. 24		138		21.71		12.04	

1/ Computed by Blaney-Criddle Method
2/ Moisture Reserve = Summation of precipitation (Oct. to April) x 80% = 3.62"
3/ Difference = Moisture Reserve plus precipitation minus moisture use
4/ Natural precipitation during most years is inadequate to meet potential moisture needs. In average years, the plants use the available moisture by July 15 and mature and become dormant.

period exceeds normal precipitation and normal moisture reserves, so maximum production is only achieved in years of high precipitation. Under normal conditions, the available moisture level is depleted by mid-July and the grasses that have not matured become dormant. Table 1 shows the average moisture requirements for native grasses and the moisture available throughout the growing season.

Water-short years do occur which could prevent successful revegetation for that year. Other climatic hazards, that occur randomly in this area, are hail and high-intensity thunderstorms. Hail is not expected to be a serious problem; but high-intensity storms can be very detrimental to young plants and unconsolidated seedbeds. This hazard can be minimized by making all reconstructed slopes, 4 percent or less, good seedbed preparation and vegetative mulches of long straw or standing small grain stubble.

Wind erosion will be a problem especially on the sandy soils. Fall and early spring plants are the most susceptible; but disking long straw or grass hay into the soil or planting in standing small grain stubble will reduce wind erosion. Late spring plantings on fallow would most likely be damaged the least by wind erosion.

Frost action in the 3- to 5-foot depth will result in physical changes of the reconstructed profile. Expansion and contraction contribute to vertical cracks and fissures in the material making it a more suitable media for plants. The average climatic conditions are favorable for quick successful revegetation of disturbed land.

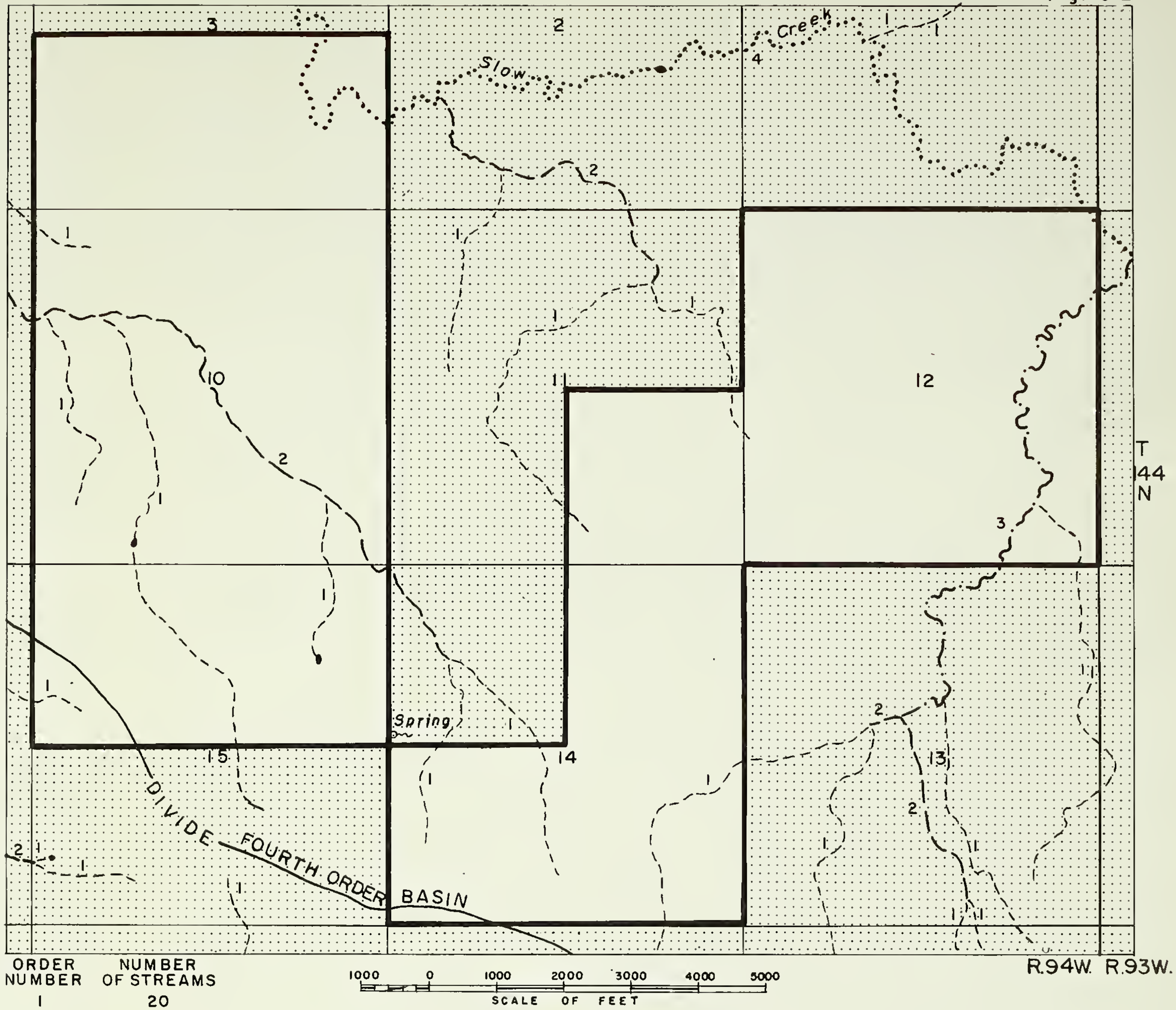
PHYSIOGRAPHY

The Horse Nose Butte Study Area lies in the glaciated portion of the Great Plains physiographic province. Topography in the area is characterized by gently rolling hills and poorly incised valleys as shown on Photographs 2 through 4. Maximum relief is about 180 feet, ranging from an elevation of 2170 feet at Slow Creek to 2350 feet on topographic highs within the study area. Surface gradients range from near flat along the Slow Creek flood plain to about 15 percent along the flanks of knobs. The area is dry farmed except for some pastureland generally situated along steeper slopes.

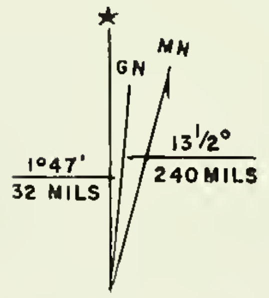
Drainage in the area is northwards into Slow Creek which flows into Spring Creek, a tributary of the Knife River. Figure 2 shows the drainage system in the study area and stream order designations. Topographic data were not available for the headwaters of Slow Creek when this figure was completed.

There are some small undrained basins in the study area. These will be eliminated during mining and reclamation. Post-mining drainageways must become an integral part of the surrounding drainage system. This system must provide adequate capacity for runoff generated within the area and from adjacent areas that would pass through the study area.

Figure 2



ORDER NUMBER	NUMBER OF STREAMS
1	20
2	5
3	1
4	1



UTM GRID AND 1973 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

QUADRANGLE LOCATION

PORTION OF U.S.G.S. DUNN CENTER QUADRANGLE

STUDY AREA NOT STIPPLED

RESOURCE & POTENTIAL RECLAMATION EVALUATION

HORSE NOSE BUTTE STUDY AREA

DUNN CENTER LIGNITE FIELD

DESIGNATION OF STREAM ORDERS

PHOTOGRAPH 2 - HORSE NOSE BUTTE STUDY AREA - DUNN CENTER LIGNITE FIELD. Panoramic view of the study area looking south across the Slow Creek Valley from near the northeast corner of Section 2, T. 144 N., R. 94 W.
U. S. Bureau of Reclamation Photograph P-1305-600-8(NA) 11/20/75

PHOTOGRAPH 3 - HORSE NOSE BUTTE STUDY AREA - DUNN CENTER LIGNITE FIELD. Panoramic view northward across Section 14, T. 144 N., R. 94 W. showing typical terrain in the study area.
U. S. Bureau of Reclamation Photograph P-1305-600-9(NA) 11/20/75

PHOTOGRAPH 4 - HORSE NOSE BUTTE STUDY AREA - DUNN CENTER LIGNITE FIELD. View of ungrazed pasture-land surrounding an abandoned farmstead in the southwest quarter of Section 12, T. 144 N., R. 94 W. U.S. Bureau of Reclamation Photograph P-1305-600-10(NA) 11/20/75

GEOLOGY

Regional Geology

The Dunn Center Lignite Field is located in the Williston Basin in west-central North Dakota. This basin, a part of the Great Plains physiographic province, is a synclinal structure extending from South Dakota into Canada, a distance of about 500 miles.

The geologic history of the areas since Precambrian time includes periods of deposition, deformation, and erosion. A sequence of carbonates, sandstones, and shales, mostly of marine origin, were deposited throughout North Dakota during the Paleozoic and Mesozoic Eras. These sediments, about 14,000 feet thick in the deepest part of the Williston Basin, thin rapidly eastward and are not present in the southeastern part of the State. Several unconformities exist throughout the Paleozoic and Mesozoic sequences in North Dakota, the most notable being the pre-Mesozoic erosional surface which truncates all Paleozoic sediments.

Deformation of the Rocky Mountains to the west and associated uplifting of the Great Plains area in North Dakota began with the Laramide Revolution at the close of Cretaceous time. Intermittent uplifting continued through the Paleocene and ended in Eocene time. Materials eroded from the mountains were spread in thick sheets over most of the Great Plains by the middle of the Cenozoic Period. A second regional uplift which occurred during the Pliocene and Pleistocene times elevated sediments to their present position. Streams rejuvenated by the uplift began stripping Tertiary strata from the Great Plains and exhuming the buried mountain masses to the west.

During the Pleistocene Epoch, several continental ice sheets invaded most of North Dakota. A sequence of till, outwash, and associated glacial debris was deposited during the advance and retreat of each ice sheet.

Today, shales, siltstones, and sandstones of Cretaceous and Tertiary age cover the western part of North Dakota. Pleistocene and Recent glacial, aeolian, and alluvial deposits mantle the bedrock in much of the area. Plate 4 is a generalized bedrock geologic map showing the southern limits of glaciation.

Area Geology

Investigations

Surface and subsurface investigations were conducted by the Bureau of Reclamation at the Horse Nose Butte Study Area between September of 1975, and February of 1976. These investigations included mapping the surface geology and drilling a series of core holes.

Geologic mapping on a scale of 1 inch equals 1000 feet was done in the field on aerial photographs. These data were transmitted to a topographic map of the same scale and are shown on Plate 5. Plate 6 is a stratigraphic column describing lignite beds shown on Plate 5.

Twenty-one drill holes (DH 75 or 76-101 through -121) ranging from 8.5 to 218.6 feet in depth were completed in the study area. Continuous cores were obtained from all holes for geologic logging and for the selection of coal and overburden samples for laboratory analyses. Drill Holes 76-119 through -121 were completed on the north side of the study area in an attempt to penetrate the bottom contact of the Dunn Center lignite bed. This was unsuccessful as all three holes collared below the lignite. The locations of core holes are plotted on the Geologic and Investigations Map, Plate 5. Plates 7 through 9 are geologic profiles correlating lignite horizons between drill holes. Detailed geologic logs are shown on Plates 10 through 21, Appendix A.

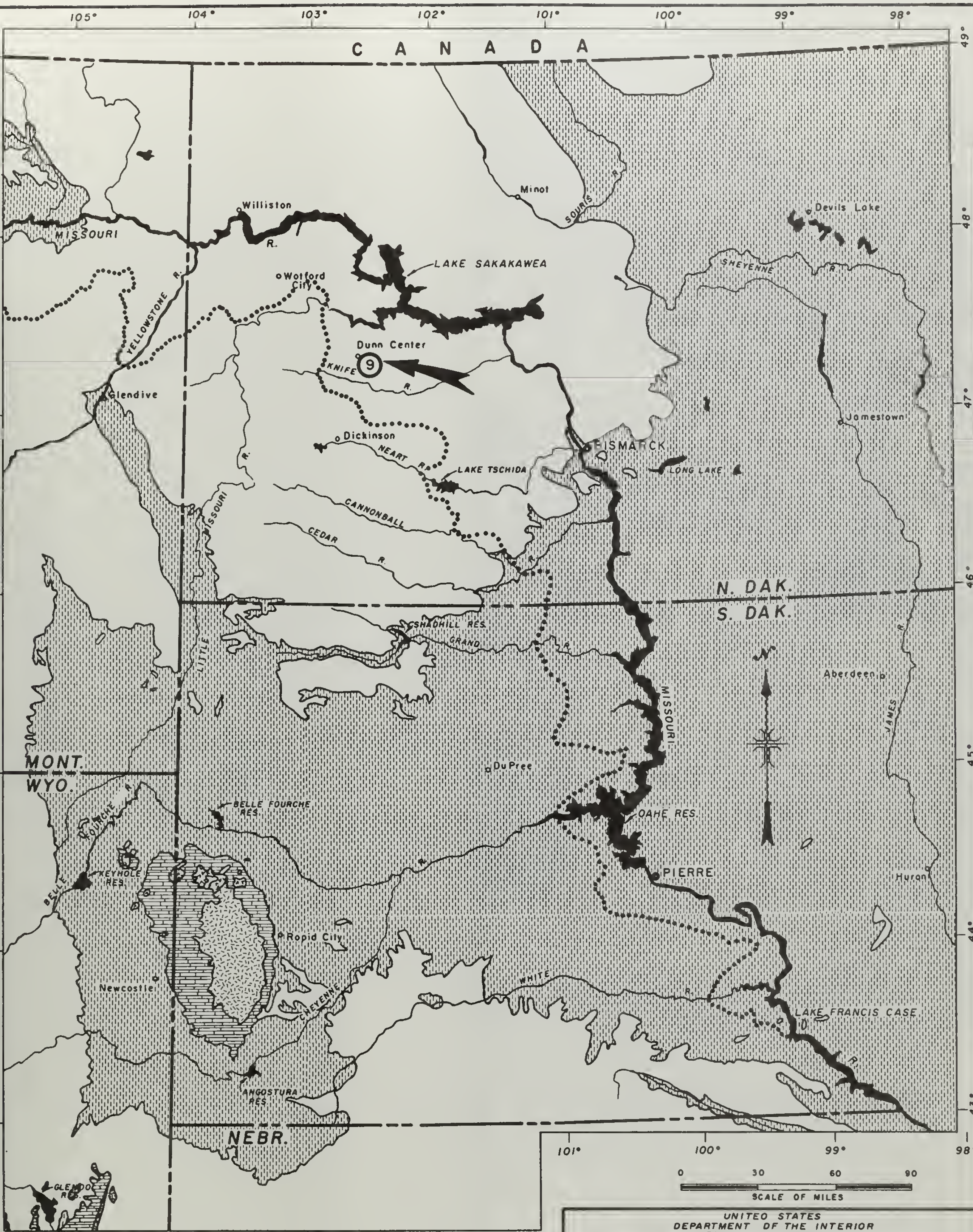
Three observation wells were drilled in the area for ground-water studies that are being conducted by the U.S. Geological Survey. Plastic pipes ranging from 2- to 4-inch inside diameter were installed in each hole and sandpacked in selected lignite zones. Geologic logs are not available as these holes were not cored.

All drilling was performed with a DAMCO Model 1250 rotary drill rig. Wire line drill tools with an "H" series barrel were used to recover core samples in most holes. Use of drilling tools larger than the standard exploratory sizes was dictated by (1) necessity to maximize core recovery, (2) provide sufficient sample for laboratory and greenhouse studies from zones as thin as 5 feet, and (3) to minimize the contamination potential.

Except for drive sampling in the upper weathered zones, all of the drilling were accomplished using bottom discharge core bits set with tungsten carbide inserts. Both preset and field set bits were used. The chief advantage of field setting is better control of bit gage, both inside and outside, which in some of the softer rocks can be used to increase core recovery.

The recovered drill cores were placed in 5-foot-long core boxes and covered by a sheet of 4-mil polyethylene plastic. This prevented a loss of moisture and a change of physical state in the core until logging and sampling could be accomplished.

Water from Spring Creek was used as the drilling fluid in all holes. Tests conducted by the U.S. Bureau of Reclamation soils laboratory



	CENOZOIC
	CENOZOIC (IGNEOUS)
	MESOZOIC
	PALEOZOIC
	PRECAMBRIAN

•••••• SOUTHERN LIMITS OF GLACIATION

⑨ HORSE NOSE BUTTE STUDY AREA—EMRIA NO.9

NOTE: COMPILED FROM STATE GEOLOGIC MAPS

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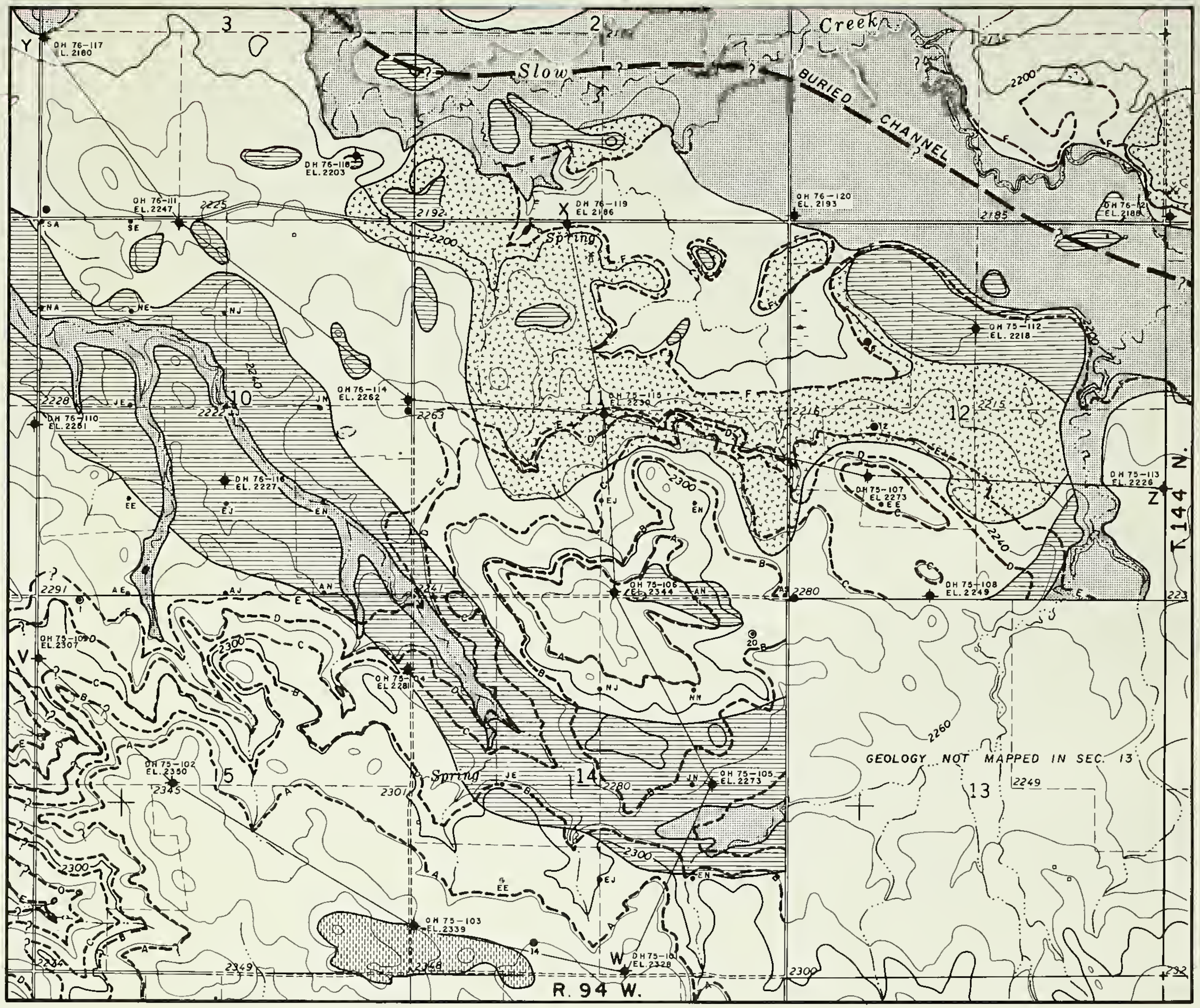
RESOURCE & POTENTIAL RECLAMATION EVALUATION
EMRIA STUDY AREAS
NORTH DAKOTA, SOUTH DAKOTA, MONTANA & WYOMING

GENERALIZED REGIONAL GEOLOGIC MAP

DESIGNED V. LINSSEN, G. TAUCHER ____ SUBMITTED ____
DRAWN V. LINSSEN ____ RECOMMENDED ____
CHECKED G. J. T. ____ APPROVED ____

BILLINGS, MONTANA MARCH 1976 | 1305-600-78



EXPLANATION

RECENT	(pattern)	ALLUVIUM—unconsolidated clay, silt, sand gravel. Includes possible Pleistocene channel fill.
RECENT	(pattern)	AEOLIAN—unconsolidated dune and loess-like deposits of clay, silt and sand which generally mantle the entire area. Varies from several inches to over 5 feet thick. Only prominent dune area in S½ of Sec. 14 & 15 was mapped.
PLEISTOCENE	(pattern)	GLACIAL TILL—heterogeneous mixture of clay silt, sand gravel, cobbles and boulders deposited by a Wisconsin age ice sheet. Isolated patches generally indicate concentrations of glacial erratics. Up to 30 feet thick.
PALEOCENE	(pattern)	SENTINEL BUTTE FM—FT. UNION GROUP—Sandstone, siltstone, shale and coal up to 500 feet thick. Almost entirely covered by alluvial, aeolian or glacial till deposits.
	(pattern)	CLINKER—baked sandstone, siltstone and shale of the Sentinel Butte Fm. Produced by burning of the Dunn Center (F) lignite bed. Up to 60 feet thick.
	—A—E—	Top of lignite or lignitic shale bed. Up to 11 feet thick.
	——F——	Base of Dunn Center lignite bed (F). Also indicates base of clinker where lignite has been burned away.

NOTE: Beds A through E are shown as they would crop out if projected to ground surface. See stratigraphic column, plate 6

- USBR drill hole (DH 75 or 76-101 thru -121) Ground elevation shown
- USGS ground water observation well.
- USBR soils auger holes that encountered lignite (1, 8, 12, 14 & 20)
- Natural Gas Pipeline Co. of America Drill Hole

V-W, W-X & Y-Z Limits of geologic sections

N

1000 0 1000 2000 3000

SCALE OF FEET

UNITED STATES
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BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

GEOLOGIC AND INVESTIGATIONS MAP

GEOLOGY G. TAUCHER SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONT. MARCH 1976 | 1305-600-79

STRATIGRAPHIC COLUMN—LIGNITE & LIGNITIC SHALE BEDS HORSE NOSE BUTTE STUDY AREA—DUNN CENTER LIGNITE FIELD NORTH DAKOTA

(PORTION OF SENTINEL BUTTE FORMATION PENETRATED BY DRILLING)

A— Lignite—0.4 to 3.4—ft. thick (Av. 1.9—ft.). 105 to 145—ft. above Bed F.

B— Lignite—7.5 to 11.0—ft. thick (Av. 9.1 ft.). 73 to 111—ft. above Bed F.

C— Lignite and Lignitic shale—0.1 to 1.9—ft. thick (Av. 1.1—ft.). 45 to 100—ft. above Bed F.

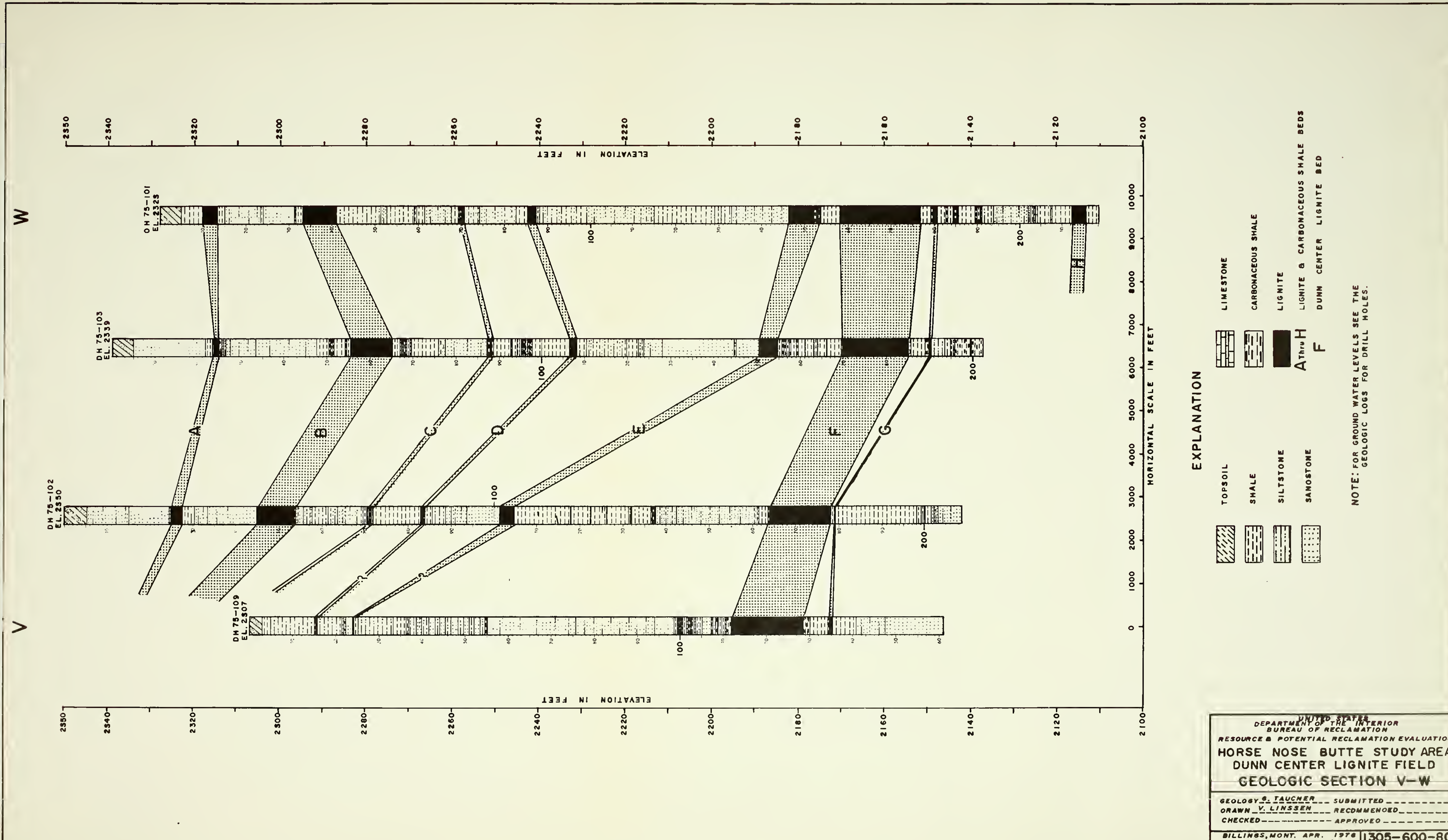
D— Lignite—0.1 to 1.9—ft. thick (Av. 1.2—ft.). 10 to 95—ft. above Bed F.

E— Lignite—0.1 (?) to 9.2—ft. thick (Av. 6.5 ft.). 3 to 88 (?)—ft. above Bed F. Thins in western and southern portions of study area.

F— Lignite (Dunn Center Bed) 14.3 to 22.1—ft. thick (Av. 18.4—ft.).

G— Lignite—0.2 to 2.7—ft. thick (Av. 1.2—ft.). 1 to 6 ft. below Bed F. Absent in places.

H— Lignite—3.5—ft.± thick. 35—ft.± below Bed F.



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DEPARTMENT OF THE INTERIOR
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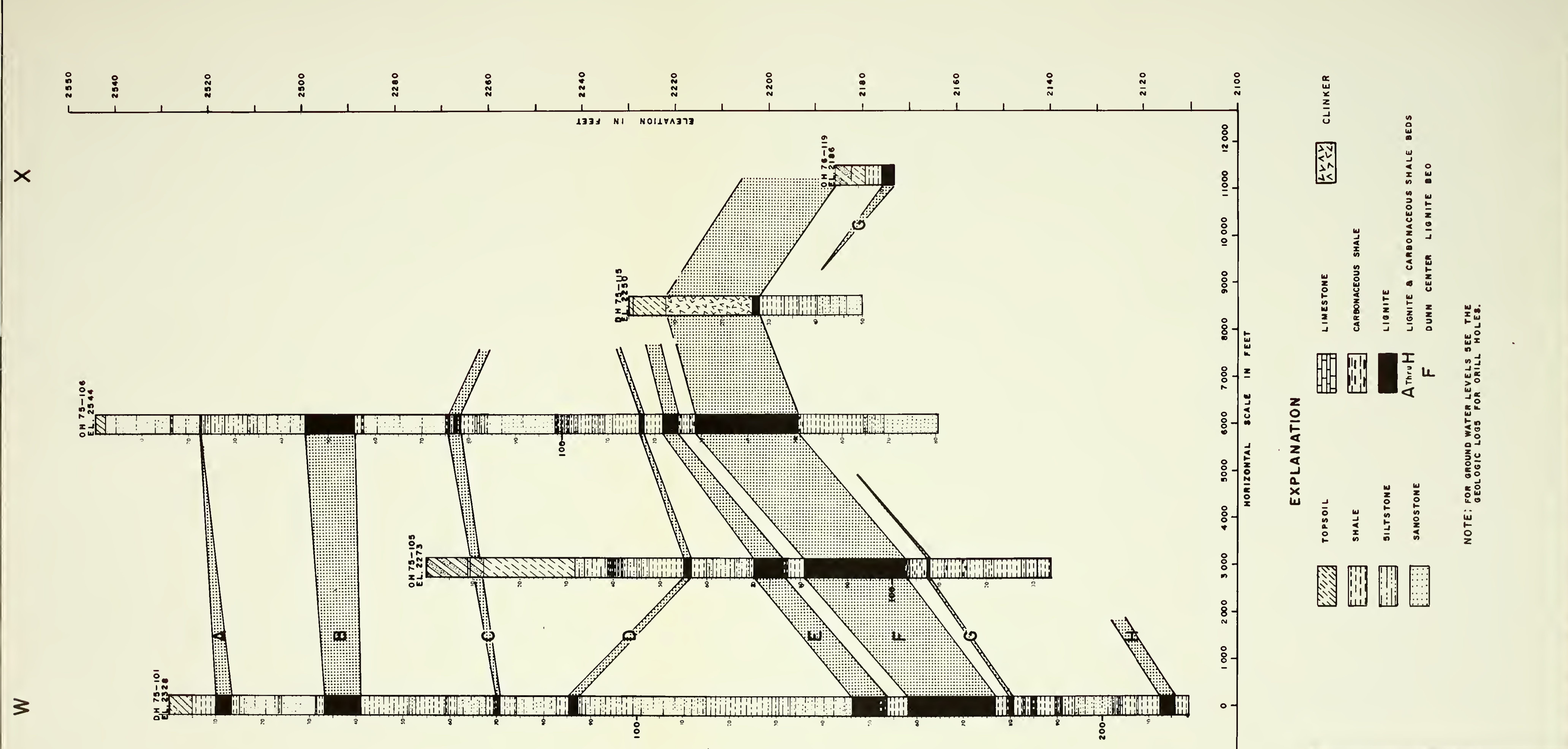
RESOURCE & POTENTIAL RECLAMATION EVALUATION

HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD
GEOLOGIC SECTION V—W

GEOLOGY G. TAUCHER SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONT. APR. 1976 1305-600-80

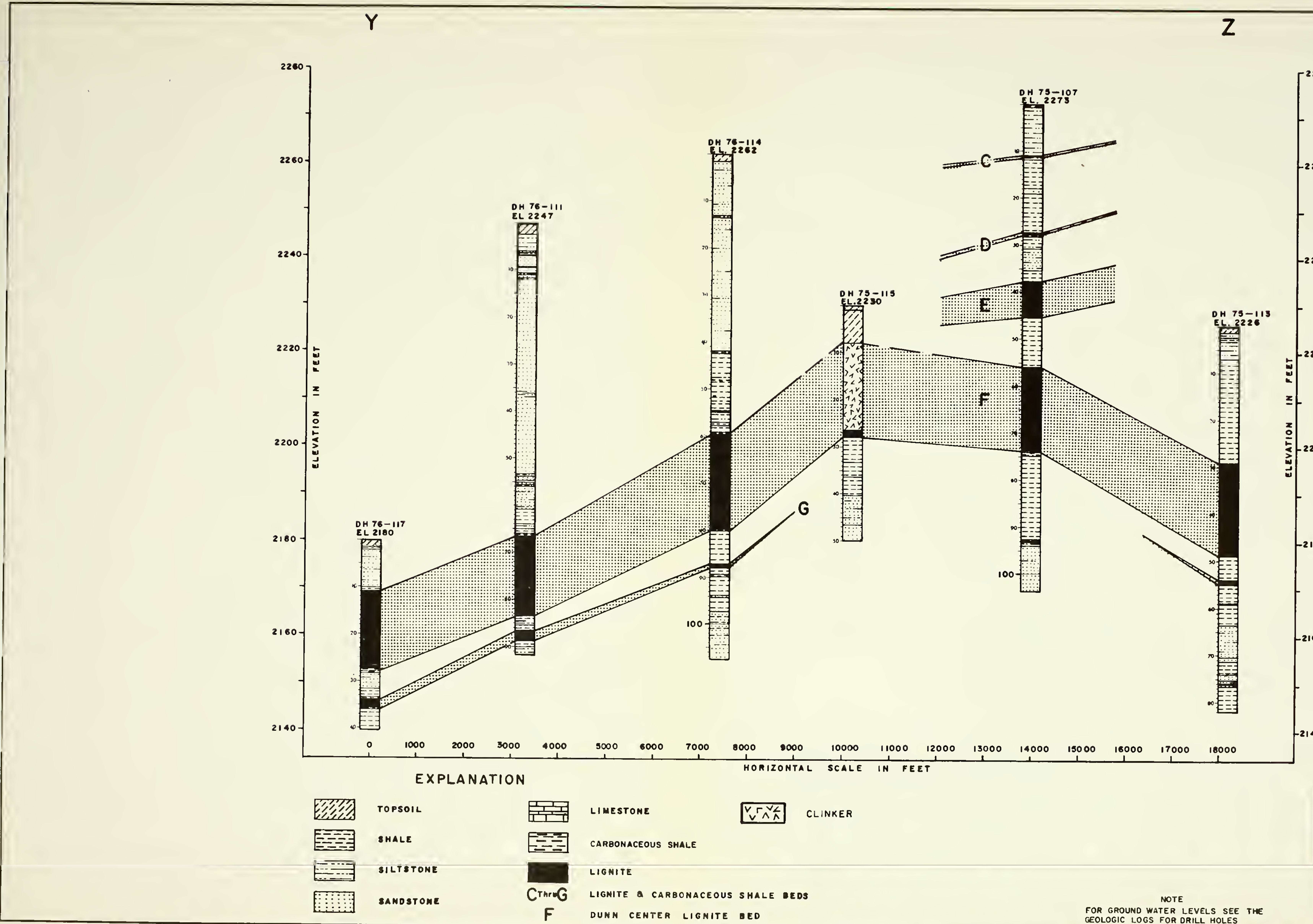
Plate 8



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION

HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD
GEOLOGIC SECTION W—X

GEOLOGY S. TAUCHER SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
CHECKED APPROVED
BILLINGS, MONT. APR. 1976 | 1305-600-81



UNITED STATES
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HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD
GEOLOGIC SECTION Y—Z

GEOLOGY G. TAUCHER SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
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BILLINGS, MONT. APR. 1976 1305-600-82

in Miles City, Montana, indicated that the total concentration of dissolved solids in the water ranged from 990 to 1280 parts per million. An organic polymer, "Revert," was used in the drilling fluid in zones where lost circulation occurred. This was chiefly in highly fractured or jointed coals.

Field checks made by adding a fluorescent dye (Fluorescein) to the drill water and checking the obtained cores under an ultra-violet black light indicate that penetration by the drill fluid, if any, is less than 1 millimeter in permeable sandstone and can be readily removed in sample preparation. Impermeable siltstone and shale samples showed no evidence of dye contamination.

Stratigraphy

The oldest rocks exposed in the study area are of Paleocene Age. In North Dakota, the State Geological Survey has divided the Paleocene Series into the Ludlow-Cannonball, Tongue River, and Sentinel Butte Formations of the Fort Union Group. These subdivisions will also be used in this section of the report. Only the Sentinel Butte, the youngest formation of the Fort Union Group, is involved in the study area. Sandstones, siltstones, and shales of this formation are locally mantled by Quaternary glacial, aeolian, and alluvial deposits. Photographs 2 through 4 show the typical rolling terrain which has been altered by glaciation.

Fort Union Group - Paleocene

Cannonball-Ludlow Formation - These sediments underlie but do not crop out in the study area. The Cannonball is the youngest known marine strata in the Northern Great Plains region. It consists of shale and thin-bedded sandstone which thins and interfingers westward with the continental deposited Ludlow.

Tongue River Formation - consists of an alternating sequence of fluvial deposited sandstone, siltstone, and shale with associated beds of lignite. It is similar to the overlying Sentinel Butte Formation, and in places, cannot be distinguished from it.

Sentinel Butte Formation - consists of an alternating sequence of sandstone, siltstone, shale, carbonaceous shale, and lignite with thin calcareous or siliceous cemented concretions. In general, the sandstones are fine grained and uncemented. Shales vary from soft, plastic clayshale to moderately indurated claystone. Shale and siltstone zones readily break down and form slopes beneath sandstone ledges. Correlation of clastic sediments over short distances is difficult due to facies changes, channeling and variation in bedding thickness. Laboratory analyses conducted on core samples from the Horse Nose Butte Study Area indicate that chemical and physical properties of the bedrock cannot generally be projected between drill holes. Weathered exposures are generally pale olive or yellowish-gray in color; while fresh core samples vary from light to dark gray. Marcasite and/or pyrite nodules are found along zones of higher permeability, such as fractures and bedding planes. The Sentinel Butte Formation was deposited under a continental environment which included swamps conducive to the production of thick lignite beds. Lignite zones serve as excellent marker beds as they can generally be traced over wide areas. This formation is about 500 feet thick. Drilling at the Horse Nose Butte Study Area penetrated a 210-foot stratigraphic section in the formation. Detailed geologic logs are shown on Plates 10 through 21, Appendix A.

One striking feature in the Sentinel Butte and Tongue River Formations is the resistant clinker zones, locally called "scoria," that cap knobs or armor valley walls. The clinker, which is fused or baked rock, was produced by the burning of lignite beds along and back from their outcrops. In places where the heat was sufficiently intense, the clinker has been fused to a dark gray, lightweight rock similar in appearance to vesicular basalt. Near the outer edge of thermal metamorphism, the rock is disoriented, baked, and red to orange in color. Alteration of the overlying material is roughly proportional to the original thickness of lignite that has burned. A lignite bed 20 feet thick will produce clinker zones 40 to 60 feet thick. The clinker is highly permeable and locally supplies water for springs and wells.

Clinker in the Horse Nose Butte Study Area was produced by burning of the Dunn Center lignite bed. Outcrops occur along the valley walls of Slow Creek as shown on the Geologic and Investigations Map, Plate 5. Some of the Dunn Center lignite undoubtedly remains beneath the clinkered areas. Evidence supporting this is the soil auger holes that encountered coal surrounded by clinker in the west half of Section 12, T. 144 N., R. 94 W. Subsurface explorations and surface mining in other areas also indicate that lower sections of thick coalbeds have not always burned beneath clinkered areas. An extensive drilling program would be required to determine the amount of coal which underlies the thermally altered rock. For the purpose of this report, it is assumed (1) that all lignite has burned beneath clinkered areas and (2) that the contact between baked and unbaked rock is vertical. A typical highly altered clinker deposit is shown in Photograph 6.

PHOTOGRAPH 5 - HORSE NOSE BUTTE STUDY AREA - DUNN CENTER LIGNITE FIELD. View of till mantled ridge with scattered erratics in the northwestern part of Section 13, T. 144 N., R. 94 W.
U. S. Bureau of Reclamation Photograph P-1305-600-11(NA)
11/20/75

PHOTOGRAPH 6 - HORSE NOSE BUTTE STUDY AREA - DUNN CENTER LIGNITE FIELD. View of masses of clinker resulting from burning lignite along a ridge in the southern portion of Section 12, T. 144 N., R. 94 W.
U.S. Bureau of Reclamation Photograph P-1305-600-12(NA)
11/20/75

Golden Valley Formation - Eocene - consists of about 200 feet of alternating shales, siltstones, and crossbedded sandstones. These sediments, which overlie the Sentinel Butte Formation, have been eroded away in the study area.

Arikaree Formation - Miocene - consists of about 400 feet of lacustrine limestone interfingering with crossbedded sandstone that caps the Killdeer Mountains northwest of the study site. Part of these sediments could include Oligocene deposits of the White River Group.

Channel Deposits - Pleistocene - consists of sand and gravel of an undetermined thickness beneath alluvial deposits along the Slow Creek Valley. The approximate channel axis is shown on the Geologic and Investigations Map, Plate 5. These deposits appear to predate early Wisconsin till in the area.

Glacial Till - Pleistocene - consists of heterogeneous mixture of clay, silt, sand, gravel, cobbles, and boulders deposited by continental glaciers. Present information indicates that two ice sheets invaded the Horse Nose Butte Study Area, the most recent being of early Wisconsin Age. Glacial erratics found west of the early Wisconsin drift limits in Dunn County support the theory that an older pre-Wisconsin ice sheet also invaded the area.

Subsurface explorations in the study area show that the thickest till deposits lie in the topographic saddle that extends through Section 10 and 14, T. 144 N., R. 94 W. Drill holes 75-105 and 76-116 encountered till to depths of 31.8 and 27.0 feet, respectively. Isolated patches of till and erratics that have not been removed by erosion are shown on the Geologic and Investigations Map, Plate 5. A typical cluster of glacial boulders is shown in Photograph 5.

Aeolian Deposits - Pleistocene and Recent - unconsolidated dune and loess-like deposits from several inches to over 5-feet-thick mantle most of the study area. The loess-like deposits consist of silty clays, clayey silts, and silty to clayey sands. A vertical root hole structure apparent in places is not as well developed as that found in loess deposits in Iowa and Nebraska. The loess-like deposits are probably late Pleistocene and Recent in age. Recent dunes, consisting of silt and very fine uniform sand, have been deposited on the lee side of knobs and ridges. One such deposit was mapped in the southern halves of Section 14 and 15, T. 144 N., R. 94 W.

Alluvium - Recent - consists of clay, silt, sand, and gravel that mantle valley floors in the study area. These sediments could be up to 20 feet thick in the Slow Creek flood plain.

Lignite Beds

Eight persistent lignite and/or lignitic shale beds, A through H, were penetrated by drilling in the Horse Nose Butte Study Area. Brief descriptions of these beds are found on the generalized stratigraphic column, Plate 6. Six of the beds, A through F, are shown on the Geologic and Investigations Map, Plate 5 as they would occur if projected to ground surface.

Four of the coalbeds may be of economic significance. These include Beds A, B, E, and F (Dunn Center bed).

Bed A varies from 0.4 to 3.4 feet thick and averages 1.9 feet thick in the study area. Thicker sections of this bed could be selectively mined.

Two other mineable lignite zones occur above the Dunn Center lignite bed. These include Beds B and E which average 9.1 and 6.5 feet thick, respectively.

The Dunn Center (F) lignite bed ranges from 14.3 to 22.1 feet thick and averages 18.4 feet thick in the study area. Overburden, interburden, and coal above the Dunn Center bed ranges from 10 to 200 feet in thickness. Depth to the Dunn Center lignite bed is shown on the Overburden Thickness Map, Plate 22.

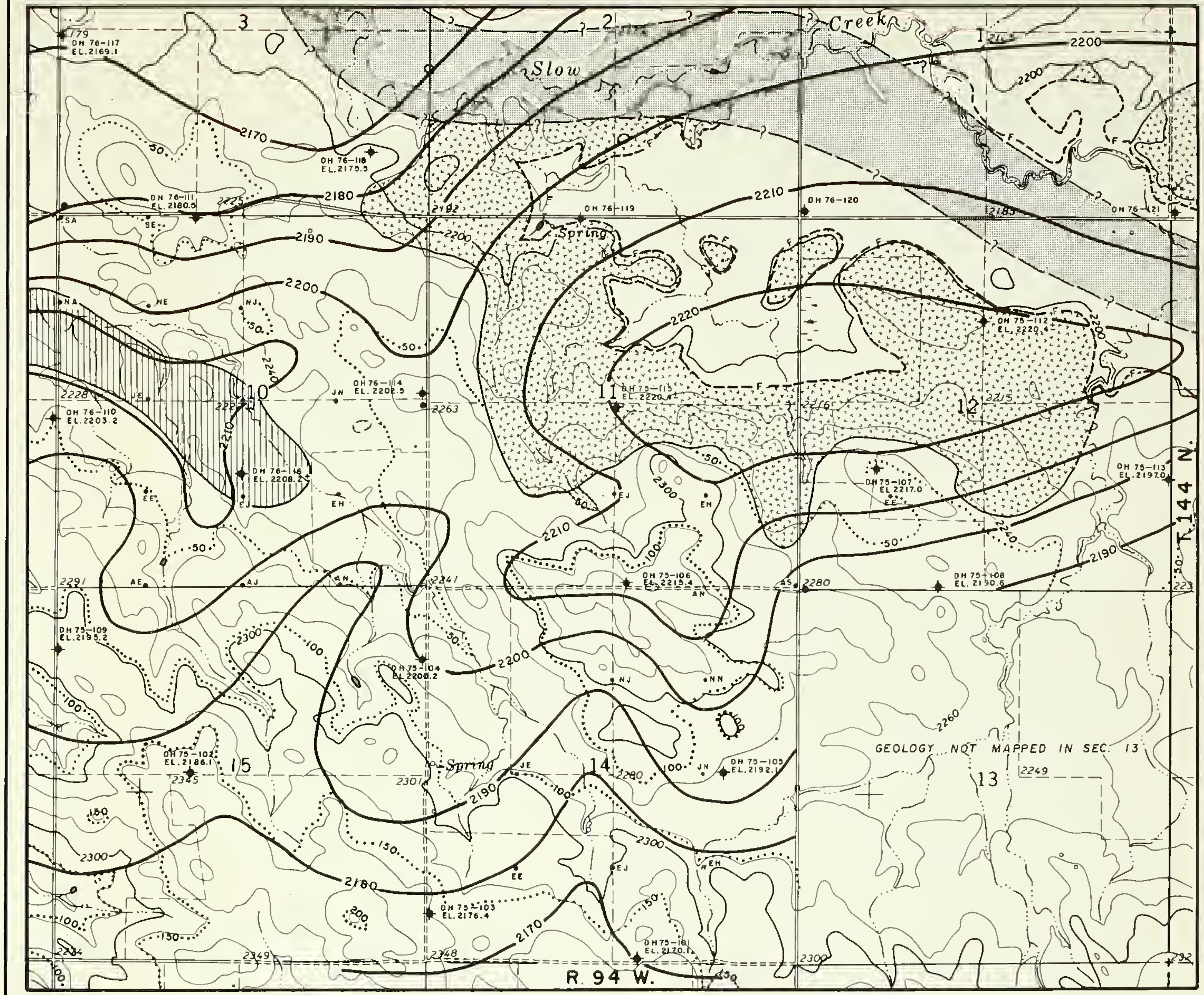
Structure

The study area is located near the center of the Williston Basin. Sediments in the area are essentially flat lying. Bedding in drill core samples was generally near horizontal except in Drill Hole 76-114 where dips of up to 35° were measured. Structure contours developed on top of the Dunn Center lignite bed, Plate 22, indicate that an east-west anticline trends across the area. Contours developed for stratigraphically higher lignite beds did not reflect a similar structure.

Small local faults exist throughout the area as indicated by the slickensides exhibited in drill core samples. These are generally restricted to weak, plastic, carbonaceous shales immediately above or below lignite beds. Displacement along these fractures could not be determined but should not exceed 5 feet.

Paleontology

Geologic mapping did not reveal any significant or unusual paleontological sites in the study area. Fossils in the Sentinel Butte Formation are generally obscured by the mantle of glacial, aeolian or alluvial soils. Fossils found in drill core samples included calcareous shells and poorly silicified or carbonaceous tree fragments. None of these were collected for identification.



EXPLANATION

- Approximate limits of buried channel. Dunn Center lignite bed not present.
- Altered shale, siltstone and sandstone (clinker) produced by burning of the Dunn Center lignite bed.
- Area in which part of Dunn Center lignite bed has been eroded away. Subsurface investigations indicate that the lignite remaining averages 12-ft. in thickness. Associated clinker deposits could underlie glacial till in or adjacent to this area.
- — — F — — Base of Dunn Center lignite bed (F). Also indicates base of clinker where lignite has burned away.
- —2170— Structure contour on top of Dunn Center lignite bed.
- ····100···· Overburden thickness contour.—Top of Dunn Center lignite bed.
- ✦ USBR Drill Hole (DH 75 or 76-101 thru-121) Elevation on top of Dunn Center lignite bed
- ● USGS Ground Water Observation Well.
- • Natural Gas Pipeline Co. of America Drill Hole

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SCALE OF FEET

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

OVERBURDEN THICKNESS MAP

GEOLOGY S. FAUCHER SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONT. MARCH 1978 1305-600-95

Engineering Geology

Engineering Properties

Engineering property tests were not conducted on overburden samples from the Horse Nose Butte Study Area. However, physical properties of these sediments should be similar to the results obtained for Fort Union samples at the Otter Creek Study Site (EMRIA Report No. 1) by the U.S. Geological Survey. Shear strengths of these materials are low, especially in a saturated condition. Slides could easily develop adjacent to highwalls in surface mines, namely along beds of weak, plastic, carbonaceous shales, which are typically cut by inherent slickensides. Adequate drainage should be insured to relieve pore-water pressures in the overburden as mine excavations progress.

Saturated, uncemented siltstones and fine-grain sandstones will readily erode and flow into excavations. This problem was encountered in drilling when the walls of some holes continued to collapse and slough until casing was installed. Depth of excavations below the water table will be limited until these types of materials are unwatered.

Excavation slopes will vary considerably between mine sites and will be dependent upon exposure time, moisture conditions, material types and depth of cut. Detailed engineering studies of the overburden will be required at each location for use in determination of designed slopes.

Studies conducted at Otter Creek indicate that disturbed overburden (spoil banks and piles) should have slopes not greater than 4 to 1 with berms of 50 to 100 feet in width designed on the slope surface.

Weathering Tests

Weathering tests were conducted on 11 core samples from the Horse Nose Butte Study Area. The purpose of these tests was to determine which materials would weather (break down) sufficiently to allow for their possible use as topsoil in revegetation of surface mined areas.

Samples were selected for (1) freeze-thaw, (2) wet-dry, and (3) outdoor tests. The criteria developed for the testing is described as follows:

Freeze-Thaw Cycle

1. 8 hours at 23.9° C (75° F), 100 percent relative humidity (wetting/thawing)

2. 16 hours (64 hours on weekend) at -17.8° C (0° F) (freezing)

Wet-Dry Cycle

1. 8 hours at 23.9° C (75° F), 100 percent relative humidity (wetting)

2. 16 hours (64 hours on weekends) at 37.8° C (100° F), 10 percent relative humidity (drying)

Outdoor

The outdoor exposure test included subjecting the specimens to 2.5 cm (1 in.) of precipitation during seven snowstorms and between 40 and 50 freeze-thaw cycles.

All core specimens were 5 cm (2 in.) in diameter by 5 cm (2 in.) in length. Tests were started on December 23, 1975, and completed after 43 laboratory weathering cycles on March 1, 1976.

Only 3 of the 11 samples broke down sufficiently for use as a planting media (breakdown based on 30 percent of material by weight passing No. 10 screen as per discussion with Dr. William Borg, Agronomy Department, Colorado State University). These samples consisted of silty shale and shale. Other shale samples showed evidence of saturation and swelling and would undoubtedly break down under additional testing. Handling and placing these soils in a moist condition may be difficult due to their plastic characteristics. Sandstone and siltstone samples were more resistant to weathering than shales. The freeze-thaw condition is more severe than the wet-dry in that it caused more rapid breakdown of most overburden materials.

COAL RESOURCES

Origin

Coal has been defined as "a readily combustible rock containing more than 50 percent by weight and more than 70 percent by volume of carbonaceous material, formed from compaction or induration of variously altered plant remains similar to those of peaty deposits. Differences in the kinds of plant materials (type), in degree of metamorphism (rank), and range of impurity (grade), are characteristics of the varieties of coal" (Schopf, 1956). Inherent in the definition is the specification that the coal originated as a mixture of organic plant remains and inorganic mineral matter that accumulated in a manner similar to that in which modern-day peat deposits are formed. The peat then underwent a long-extremely complex process called "coalification" during which diverse physical and chemical changes occured as the peat changed to coal and the coal assumed the characteristics by which we differentiate members of the series from each other. The factors that affect the composition of coals have been summarized by Francis (1961, p. 2) as follows:

1) The mode of accumulation and burial of the plant debris forming the deposits.

2) The age of the deposits and their geographical distribution.

3) The structure of the coal-forming plants, particularly details of structure that affect chemical composition or resistance to decay.

4) The chemical composition of the coal-forming debris and its resistance to decay.

5) The nature and intensity of the plant-decaying agencies.

6) The subsequent geological history of the residual products of decay of the plant debris forming the deposits.

For extended discussions of these factors, the reader is referred to such standard works as Moore (1940), Lowry (1945), Tomkeieff (1954), Francis (1961), and Lowry (1963).

Classification

Coals can be classified in many ways (Tomkeieff, 1954, p. 9; Moore, 1940, p. 113; Francis, 1961, p. 361), but the classification by rank--that is, by degree of metamorphism in the progressive series which begins with peat and ends with graphocite (Schopf, 1966)--is the most commonly used system. Classification by types of plant materials is commonly used as a descriptive adjunct to rank classification when sufficient mega and microscopic information is available, and classification by type and quantity of impurities (grade) is also frequently used when utilization of the coal is being considered. Other categorizations are possible and are commonly employed in discussion of coal resources--such factors as the weight of the coal, the thickness and areal extent of the individual coalbeds, and the thickness of overburden are generally considered.

Rank of Coal

The position of a coal within the metamorphic series, which begins with peat and ends with graphocite, is dependent upon the temperatures and pressure to which the coal has been subjected and the duration of time of subjection. Because it is by definition largely derived from plant material, coal is mostly composed of carbon, hydrogen, and oxygen, along with smaller quantities of nitrogen, sulfur, and other elements. The increase in rank of coal as it undergoes progressive metamorphism is indicated by changes in the proportions of the coal constituents--the higher rank coals have more carbon and less hydrogen and oxygen than the lower ranks.

Two standardized forms of coal analyses--the proximate analysis and the ultimate analysis--are generally used in the work today, though sometimes only the less complicated and less expensive proximate analysis is made. The analyses are described as follows (U.S. Bureau Mines, 1965, p. 121-122):

> "The proximate analysis of coal involves the determination of four constituents: (1) water, called moisture; (2) mineral impurity, called ash, left when the coal is completely burned; (3) volatile matter, consisting of gases or vapors driven out when coal is heated to certain temperatures; and (4) fixed carbon, the solid or cakelike residue that burns at higher temperatures after volatile matter has been driven off. Ultimate analysis involves the determination of carbon and hydrogen as found in the gaseous products of combustion, the determination of sulfur, nitrogen, and ash in the material as a whole, and the estimation of oxygen by difference."

Most coals are burned to produce heat energy so the heating value of the coal is an important property. The heating value (calorific value) is commonly expressed in British thermal units (Btu) per pound: one Btu is the amount of heat required to raise the temperature of 1 pound of water 1 degree fahrenheit (in the metric system, heating value is expressed in kilogram-calories per kilogram). Additional tests are sometimes made, particularly to determine the caking, coking, and other properties, such as tar yield, which affect classification or utilization.

Figure 3, Appendix B, compares in histogram form the heating value and moisture, volatile matter, and fixed carbon contents of coals of different ranks.

Various schemes for classifying coals by rank have been proposed and used but the most commonly employed are the "Standard specifications for classification of coals by rank," adopted by the American Society for Testing and Materials (1974, Table 2, Appendix B).

The ASTM classification system differentiates coals into classes and groups on the basis of mineral-matter-free fixed carbon or volatile matter and the heating value supplemented by determination of agglomerating (caking) characteristics. As pointed out by the ASTM (1974, p. 55), a standard rank determination cannot be made unless the samples were obtained in accordance with standardized sampling procedures (Snyder, 1950; Schopf, 1960). However, nonstandard samples may be used for comparative purposes through determinations designated as "apparent rank."

Characteristics of North Dakota Coal (From Landis, 1973)

The coal of North Dakota is classified as lignite on the basis of its physical and chemical properties. Like other lignitic coals, it is high in moisture and volatile matter, and low in fixed carbon and heat value. Lignitic coals also slack easily when exposed to air and are subject to spontaneous combustion when stored.

Specimen proximate analyses and the derived average analysis of lignite samples from the nine counties in North Dakota are shown in Table 3, Appendix B. The average analysis is typical of coals classed as lignite A (Table 2, Appendix B). In terms of quality, or grade, the North Dakota lignite would be classed as low sulfur--less than 1 percent (DeCarlo and others, 1966)--and the average ash content of 6.7 percent indicates that the North Dakota lignite probably contains less ash than the average of coals produced in the United States.

The analyses of 102 tipple samples of North Dakota lignite collected in 1959 from 41 mines in 17 counties were reported by Aresco and others (1960). The range analyses are:

Moisture, as received	28.9 to 43.8 percent.
Volatile matter, dry	33 to 46.1 percent.
Fixed carbon, dry	31.9 to 51.6 percent.
Ash, dry	6.3 to 34.5 percent.
Sulfur	0.3 to 4.3 percent.
As received	5,210 to 7,550 Btu's.
Dry	7,760 to 11,320 Btu's.
Ash-softening temperature	1,940^{o} to 2,610^{o}.

Most of these samples had been sized prior to collection. Because of their lower ash content, the coarser sizes are higher in moisture, volatile matter, fixed carbon, heat value, and ash-softening temperature than the fine sizes. In general, the intermediate sizes contain more sulfur.

Ten of the aforementioned analyses, collected from nine mines in seven counties, are of mine-run samples. The range analyses are:

Moisture	35.9 to 43.8 percent.
Volatile matter, dry	41.1 to 45.3 percent.
Fixed carbon, dry	43.2 to 50 percent.
Ash, dry	6.7 to 13.2 percent.
Sulfur	0.3 to 2.7 percent.
As received	6,090 to 7,140 Btu's.
Dry	10,670 to 11,280 Btu's.
Ash-softening temperature	2,080° to 2,550°.

These results indicate, as could be expected, that the analyses of mine-run samples in general follow the pattern of the coarser sizes of the sized coal. That is, the range analysis of the mine-run samples falls into the upper part of the range analysis of the total sample for moisture, volatile matter, fixed carbon, heat value, and ash-softening temperature.

Coals from the Sentinel Butte Member in Western North Dakota

Table 4, Appendix B, presents proximate, ultimate, Btu, and forms of sulfur analyses of seven samples of lignite from the Sentinel Butte Member of the Fort Union Formation collected by C. G. Carlson of the North Dakota Geological Survey (written commun., 1976) in two mines, one each in Stark and Mercer Counties (Table 5, Appendix B).

Dunn County Lignite

No analyses are available at this time for the coals penetrated by the drill holes in the Horse Nose Butte Study Area, but the U.S. Bureau of Mines MERIT computer storage system contains 25 analyses of Dunn County coals. The samples are from uncorrelated beds but the thicker coals present in the EMRIA study area are almost certainly represented in the sample suite. The average analyses, derived from the 25 samples, are:

Moisture (as received)	40.6
Ash (as received)	7.0
Sulfur (as received)	0.6
Btu (as received)	6,310

The lignite in the Horse Nose Butte Study area is probably similar to the average cited above.

Estimation and Classification of Coal Resources

Coal resource estimates have been prepared for the Horse Nose Butte Study area using standard procedures, definitions, and criteria of the U.S. Geological Survey and U.S. Bureau of Mines established for making coal resource appraisals in the United States. The term "coal resources" as used in this report means the estimated quantity of coal in the ground in such form that economic extraction is currently or potentially feasible.

Table 6 presents the estimated demonstrated coal resources in the A, B, E, and F (Dunn Center) coalbeds in the Horse Nose Butte Study area by section, bed thickness category, and overburden thickness category. The estimated resources are summarized by bed and overburden thickness category in Table 7.

Resources Categorized by Degree of Geologic Assurance

Demonstrated coal resources are the sum of the coal in both measured and indicated resource categories.

Measured resources are coal for which estimates of the rank, quality, and quantity have been computed, within a margin of error of less than 20 percent, from sample analyses and measurements from closely spaced and geologically well-known sample sites.

Indicated resources are coal for which estimates of the rank, quality, and quantity have been computed partly from sample analyses and measurements and partly from reasonable geologic projections.

Because of the lack of definitive sample analyses of the coal in the study area itself, the estimated resources of the Horse Nose Butte area are classed as demonstrated resources. All of the estimated demonstrated resources of the study area are within 3/4 mile of points of observation.

The part of the estimated resources that are more than 5 feet thick and are at depths of 100 feet or less fall into a category called reserve base, which is defined as that portion of the identified coal resource from which reserves are calculated. Reserves are that portion of the identified coal resource that can be economically mined at the time of determination. The reserve is derived by applying a recovery factor to that component of the identified coal resource designated as the reserve base. On a national basis, the estimated recovery factor for the total reserve base is 50 percent. More precise recovery factors can be computed by determining the total coal in place and the total coal recoverable in any specific locale.

Characteristics Used in Resource Evaluation

The coal characteristics that are commonly used in classifying coal resources are the rank, grade, and weight of the coal, the thickness of the coalbeds, and the thickness of the overburden. Rank and grade have been discussed previously.

Weight

The weight of coal ranges considerably with differences in rank and ash content. In areas such as the Horse Nose Butte area, where specific gravities of the coals have not been determined, an average specific gravity value based on many determinations in other areas is used to express the weight of the coal for resource calculations. The average weight of lignitic coal is taken as 1,750 short tons per acre-foot--a specific gravity of 1.29.

Thickness of Beds

Because of the important relation of coalbed thickness to utilization potential, most coal resource estimates prepared by the U.S. Geological Survey are tabulated according to three thickness categories. For lignite the categories are thin--2.5 to 5 feet (0.75 to 1.5 m); intermediate--5 to 10 feet (1.5 to 3 m); and thick--more than 10 feet (3m).

Thickness of Overburden

Almost all of the estimated coal resources in the Horse Nose Butte Study area are overlain by 200 feet (60 m) or less of overburden.

Major, Minor, and Trace-Element Composition

Fourteen core samples of coalbeds in the Sentinel Butte Member in Stark and Mercer Counties were analyzed for the following constituents (following the procedure shown on Figure 4, Appendix B).

1. Proximate analysis for percent moisture, volatile matter, fixed carbon, and ash; ultimate analysis for percent hydrogen, carbon, nitrogen, oxygen, and sulfur; and forms-of-sulfur analysis for percent sulfate-sulfur, pyritic sulfur, and organic sulfur (see Table 4, Appendix B).

2. Major composition of the ash of coal--percent ash, SiO_2, Al_2O_3, Na_2O, K_2O, CaO, MgO, Fe_2O_3, P_2O_5, Cl, MnO, TiO_2, and SO_3.

3. Trace element composition of coal

   a. Individual quantitative determinations--ppm As, Cd, Cu, F, Hg, Li, Pb, Sb, Se, Th, U, and Zn.

   b. Semiquantitative spectrographic analysis--ppm of 20-30 elements detected by this method.

Results of the analytical determinations are listed in Tables 8, 9, and 10, Appendix B.

Table 11, Appendix B, compares analyses of 14 samples of lignite from the Sentinel Butte Member in Stark and Mercer Counties, North Dakota, to 62 samples of lignite from 9 mines in North Dakota and one mine in Montana (Swanson and others, 1974). None of the differences shown are of significant magnitude.

Table 6.--Estimated demonstrated coal resources (thousands of short tons), by bed, section, bed thickness (feet), and overburden thickness (feet)

Bed	Section	Overburden thickness	Demonstrated Resources			
			Bed thickness			
			2 1/2 - 5	5 - 10	10 and more	Total
A	11	0 - 200	180	------	------	180
B	11	0 - 200	-----	------	1,340	1,340
	14	0 - 200	-----	5,280	1,070	6,350
	15	0 - 200	-----	5,510	------	5,510
Total Bed B		0 - 200	-----	10,790	2,410	13,200
E	11	0 - 200	790	190	------	980
	12	0 - 200	-----	1,850	------	1,850
	14	0 - 200	1,640	3,920	------	5,560
	15	0 - 200	2,850	------	------	2,850
Total Bed E		0 - 200	5,280	5,960	------	11,240
F	3 (partial)	0 - 50	-----	------	6,670	6,670
	3 (partial)	50 - 100	-----	------	1,500	1,500
	Total Section 3		-----	------	8,170	8,170
	10	0 - 50	-----	------	7,540	7,540
	10	50 - 100	-----	------	4,580	4,580
	Total Section 10		-----	------	12,120	12,120
	11	0 - 50	-----	------	1,040	1,040
	11	50 - 100	-----	------	6,410	6,410
	Total Section 11		-----	------	7,450	7,450
	12	0 - 50	-----	------	3,210	3,210
	12	50 - 100	-----	------	2,270	2,270
	Total Section 12		-----	------	5,480	5,480
	14	0 - 50	-----	------	130	130
	14	50 - 100	-----	------	8,970	8,970
	14	100 - 150	-----	------	10,640	10,640
	14	150 - 200	-----	------	2,030	2,030
	Total Section 14		-----	------	21,770	21,770
	15	0 - 50	-----	------	150	150
	15	50 - 100	-----	------	4,410	4,410
	15	100 - 150	-----	------	7,610	7,610
	15	150 - 200	-----	------	4,560	4,560
	Total Section 15		-----	------	16,730	16,730
	Total	0 - 50	-----	------	18,740	18,740
		50 - 100	-----	------	28,140	28,140
		100 - 150	-----	------	18,250	18,250
		150 - 200	-----	------	6,590	6,590
Total B Bed		0 - 200	-----	------	71,720	71,720
Grand Total		0 - 200	5,460	16,750	74,130	96,340

Table 7.--Summary of estimated coal resources of the Horse Nose Butte EMRIA Study Area, by bed and overburden thickness

[In thousands of short tons]

Overburden thickness (feet)	Bed A	Bed B	Bed E	Bed F	Total
0 - 50	---	------	------	18,740	18,740
50 - 100	---	------	------	28,140	28,140
100 - 150	---	------	------	18,250	18,250
150 - 200	---	------	------	6,590	6,590
0 - 200	180	13,200	11,240	71,720	96,340

Table 12, Appendix B, shows the range of and average elemental content, on the whole-coal basis, of those constituents commonly regarded as being of importance from the standpoint of coal utilization. Some of the elements, such as mercury and arsenic, are of interest because of the environmental problems that might occur if they are present in inordinate amounts; others, such as thorium and uranium, are of interest because they could be recovered from coal ash if they are present in sufficiently large quantities. Copper, fluorine, zinc, and selenium differ with the average elemental crustal abundance by more than one order of magnitude.

HYDROLOGY

Introduction

The purpose of the study was to determine the premining hydrologic and geochemical conditions in the Horse Nose Butte Study area and to provide background data from which guidelines can be developed for mining and reclamation to minimize the adverse effects of surface mining. Location of the area is shown on Plates 1 and 2.

Many sources of data have been utilized in the preparation of this report. A well inventory (Klausing, 1976) provided data on depth, construction, productivity, and water quality of private wells adjoining the study area. Test drilling by the North Dakota Geological Survey and the North Dakota State Water Commission supplied information on the hydrology, thickness, and extent of the major geologic units and aquifer systems. Test holes drilled by the U.S. Bureau of Reclamation supplied cores for petrographic and X-ray analysis. Wells, test holes, and chemical analyses used in the study are listed in Tables 13 through 17, Appendix C.

Several unnamed intermittent streams drain the Horse Nose Butte area. They discharge northward via Slow Creek into Spring Creek, which is a major tributary of the Knife River. The Knife River flows eastward and joins the Missouri River near Stanton, North Dakota.

Geologic investigations of interest to the area have been made by Stanton (1920) and by Benson (1952). The latter report included detailed mapping in the Knife River basin. Denson and Gill (1965) also described the regional geology and studied the occurrence of uranium in the lignite deposits in parts of western North Dakota. Dingman and Gordon (1954) described the geology and ground-water resources of the Fort Berthold Indian Reservation, which includes the northern part of Dunn County. A detailed discussion of the aquifer systems in adjoining Mercer and Oliver Counties, in the lower part of the Knife River basin, is available in a report by Croft (1973).

The well-numbering system used in this report (Figure 5) is based on the federal system of rectangular surveys of the public lands. The first numeral denotes the township, the second denotes the range, and the third denotes the section in which the well, spring, or test hole is located. The letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarter section, quarter-quarter section, and quarter-quarter-quarter section (10-acre or 4-ha tract). Thus well 144-094-15ADC would be located in the SW¼SE¼NE¼ sec. 15, T. 144 N., R. 94 W.

Geohydrology

Dunn County is near the center of the Williston basin, a broad structural depression underlying parts of North Dakota, South Dakota, Montana, Manitoba, and Saskatchewan (Denson and Gill, 1965, pl. 5).

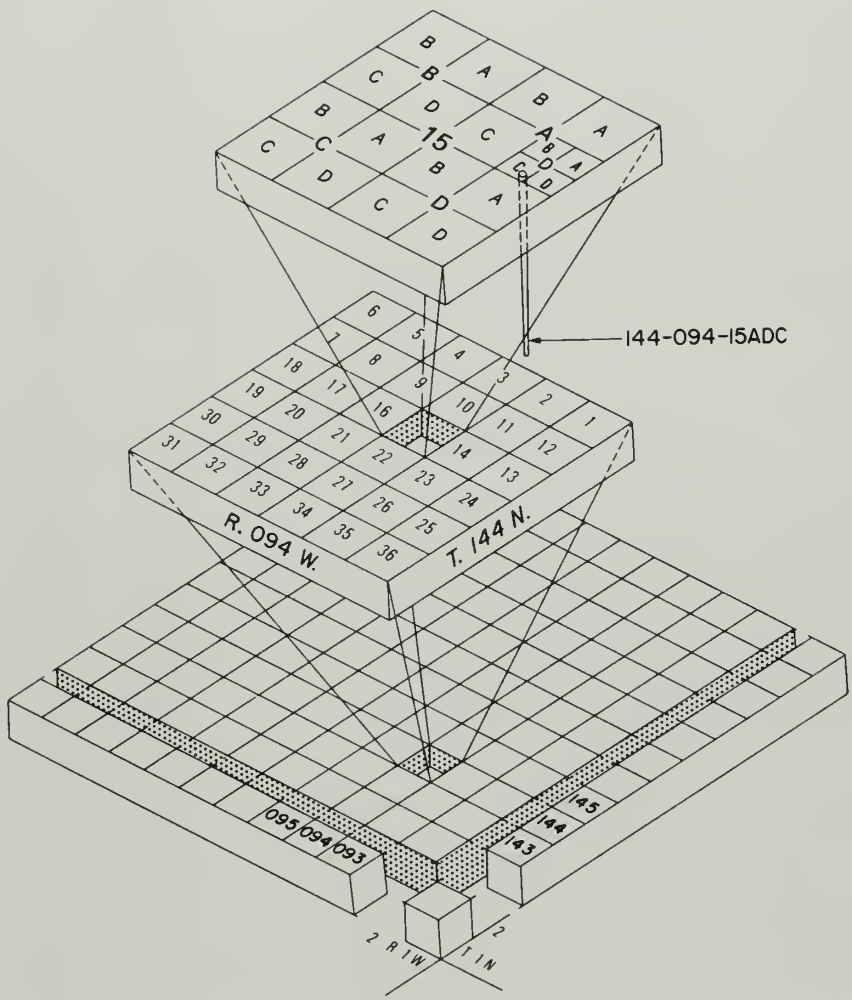


FIGURE 5.--System of numbering wells and test holes.

The center of the basin contains about 15,000 feet (4,600 m) of sedimentary rocks ranging in age from the Cambrian through the Quaternary (Table 18). During Late Cretaceous and Early Tertiary time, compressive forces folded the rocks into gentle anticlines and synclines. Regionally, all the beds, from the Deadwood Formation to the White River Formation, are warped to some degree. However, within the Horse Nose Butte area, the beds are essentially flat lying.

The aquifer systems that contain water usable for domestic, livestock, and industrial purposes are those overlying the Pierre Shale (Table 18), a formation of relatively low permeability. The Pierre Shale is a dark-gray to brownish-black fissile shale about 1,700 to 2,500 feet (520 to 760 m) thick that yields little or no water to wells. Thus, for practical purposes, it forms the base of the shallow and intermediate-depth ground-water reservoirs and is an excellent stratigraphic marker. Overlying the Pierre Shale are the: (1) Fox Hills Sandstone, (2) Hell Creek Formation, and (3) Fort Union Formation. These younger rocks have a maximum combined thickness of about 2,100 feet (640 m). In this area the Fort Union Formation can be divided into four members; the Ludlow, Cannonball, Tongue River, and Sentinel Butte.

The Fox Hills Sandstone consists of interbedded marine grayish-white to brown glauconitic sandstone and greenish-gray shale.

The Hell Creek Formation consists of continental dark-gray and brown lenticular sandstone and claystone; it is tentatively divided into three units for purposes of this study. The upper unit is predominantly sandstone and siltstone and generally yields water to wells. The middle unit is characteristically fine grained and is not an aquifer. The lower unit is similar to the upper unit and together with sandstone in the upper part of the underlying Fox Hills Sandstone is collectively referred to as the Fox Hills and basal Hell Creek aquifer system, or, in some places, simply as the Fox Hills aquifer. The cities of Golden Valley, Dodge, Halliday, and Dunn Center obtain municipal supplies from the Fox Hills and basal Hell Creek aquifer system. The aquifer system may be a possible source of water for mining and reclamation in the Horse Nose Butte area. The water from the Fox Hills and basal Hell Creek aquifer system is generally a sodium-bicarbonate type and contains about 1,200 mg/l (milligrams per liter) dissolved solids.

The Cannonball Member is a marine deposit about 400 feet (120 m) thick consisting of greenish-gray relatively impermeable sandy siltstone and claystone that interfingers laterally with the Ludlow Member, its continental equivalent. The Cannonball Member acts as a confining unit throughout the Knife River basin, separating the overlying shallow aquifers from the intermediate-depth aquifers. In adjoining southwestern Mercer County hydraulic heads in aquifers below the Cannonball Member are about 50 feet (15 m) higher than heads in aquifers above the Cannonball (Croft, 1973, Figures 14 and 15).

The Ludlow Member consists of interbedded continental sandstone, siltstone, claystone, and lignite.

The Tongue River Member consists of continental deposits of Paleocene Age that overlie the Cannonball and Ludlow Members. The beds are not exposed in the Horse Nose Butte area, but outcrop in the lower part of the Knife River basin, in the bluffs above the Missouri River south of Stanton, and in the northern part of Dunn County along the Missouri River. The member is about 500 feet (150 m) thick, and consists of interbedded light-olive-gray to dark-greenish-gray claystone, siltstone, fine-grained sandstone, and lignite. The lower part of the member contains thick crossbedded friable sandstone interbedded with siltstone and claystone. These thick sandstone units have a hydraulic conductivity of about 2 ft/d (0.6 m/d) and are potentially a source of water for mining and reclamation. The hydraulic gradient in the Tongue River Member, as shown in Figure 6, slopes to the northeast at about 5 to 10 ft/mi (1 to 2 m/km).

The Sentinel Butte Member, the uppermost unit of the Fort Union Formation, consists of about 500 feet (150 m) of silty fine- to medium-grained sandstone, siltstone, carbonaceous and bentonitic claystone, and lignite. The sandstone is generally thin bedded. The sandstone and lignite beds have an average hydraulic conductivity of less than 2 ft/d (0.6 m/d). The deposits are exposed throughout most of the study area, except where the land surface is veneered with drift. The Dunn Center lignite bed (Figure 7), the lignite unit of most economic interest in the area, is located approximately in the middle part of the member. Although farm and domestic wells obtain adequate supplies of water from various water-bearing sandstone and fractured lignite horizons within the Sentinel Butte Member, no major aquifers are present within the study area due to the low hydraulic conductivity, small thickness, and short lateral extent of the sandstone beds and fracture zones in the lignite.

The potentiometric surface of ground water in fracture and joint systems within the Dunn Center lignite bed indicates that the study area is located in a recharge area for the local ground-water flow system and the general movement of water is away from the high ridges and knolls towards Spring Creek and its major tributaries. The potentiometric head in the Dunn Center lignite bed is about 100 feet (30 m) higher than the head in the sandstone in the upper part of the Tongue River Member (Figure 6), indicating water from the Sentinel Butte Member is moving downward into the underlying Tongue River Member (Figure 8).

Geochemistry

Water samples from wells in and near the study area indicate that ground water in the Tongue River and Sentinel Butte Members is generally a sodium sulfate to sodium-bicarbonate type (Figure 9), although calcium and magnesium are major constituents in some water samples from shallow wells. Dissolved solids in eight water samples

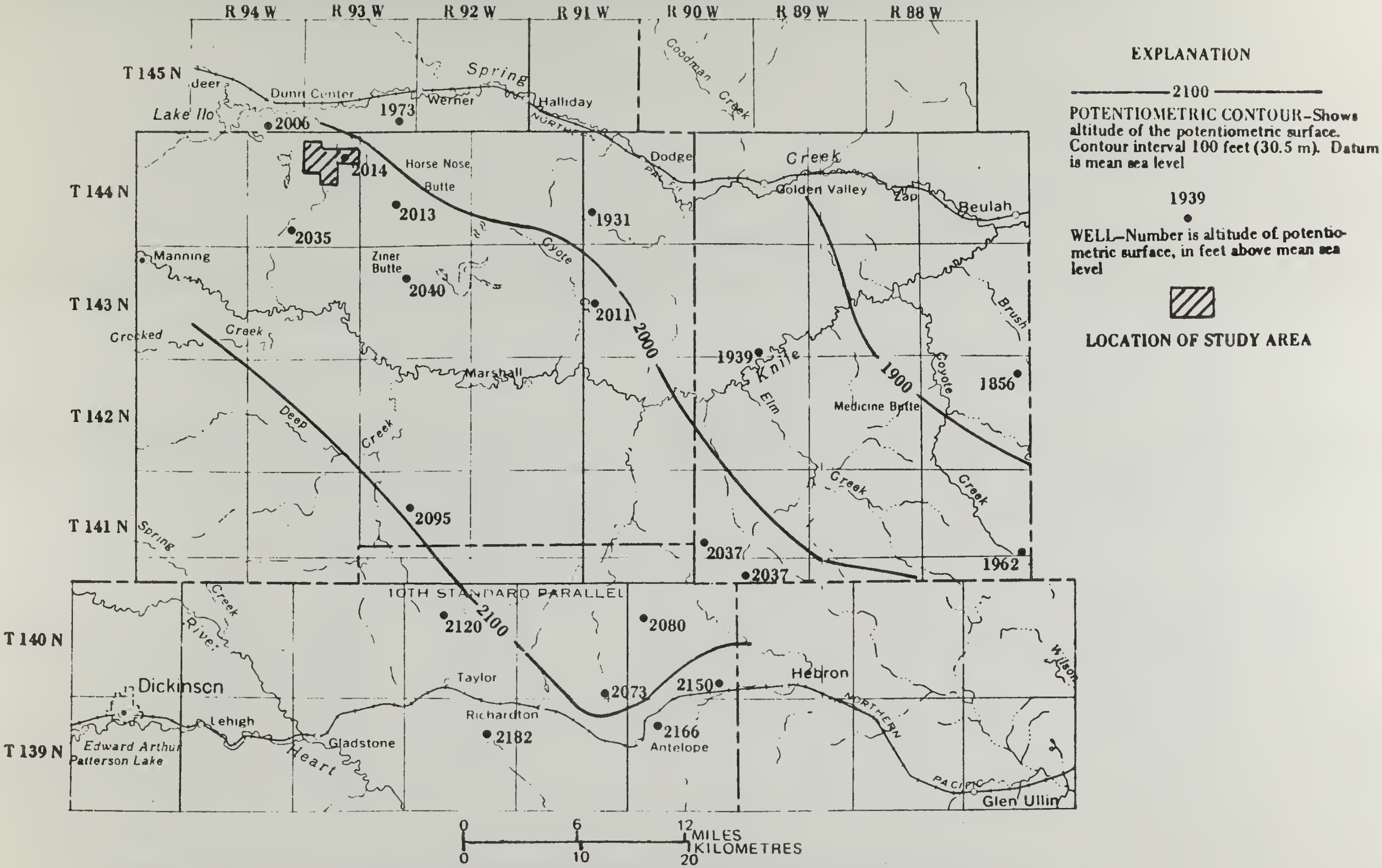


FIGURE 6 –GENERALIZED POTENTIOMETRIC SURFACE IN THE LOWER SENTINEL BUTTE AND UPPER TONGUE RIVER MEMBERS OF THE FORT UNION FORMATION (DATA FROM CROFT, 1973. KLAUSING, 1976)

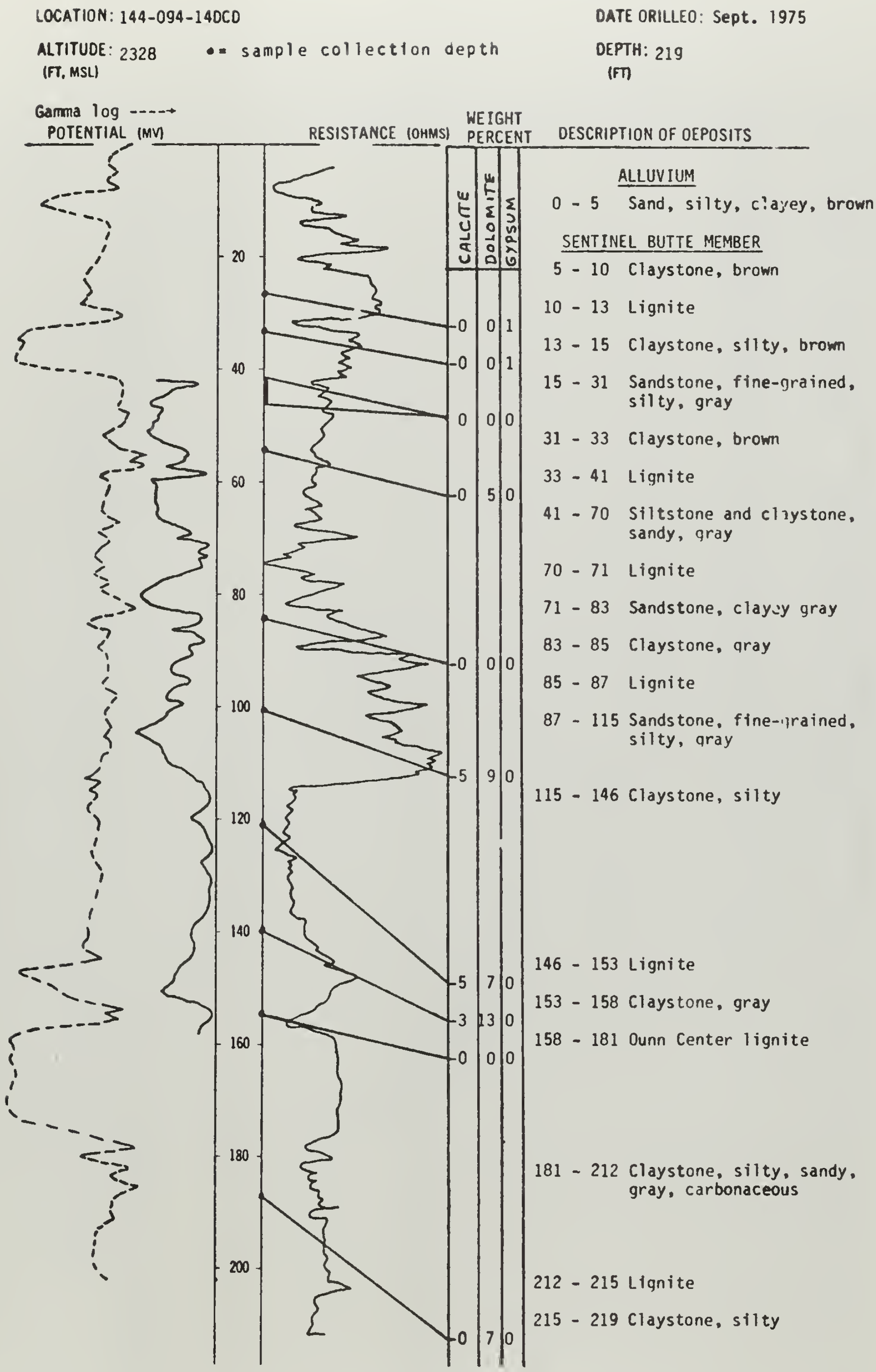


FIGURE 7 Log of USBR test hole 75-101

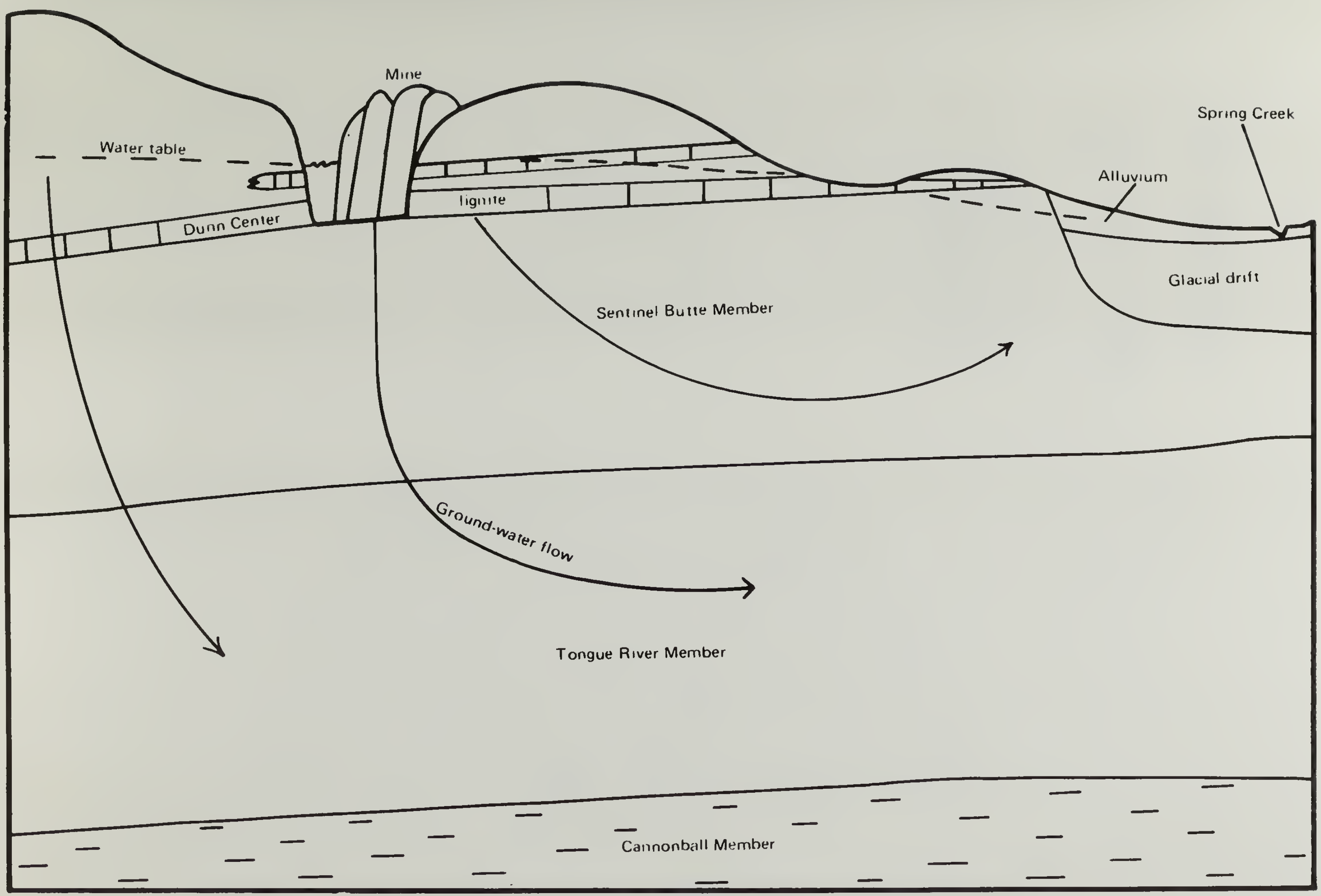
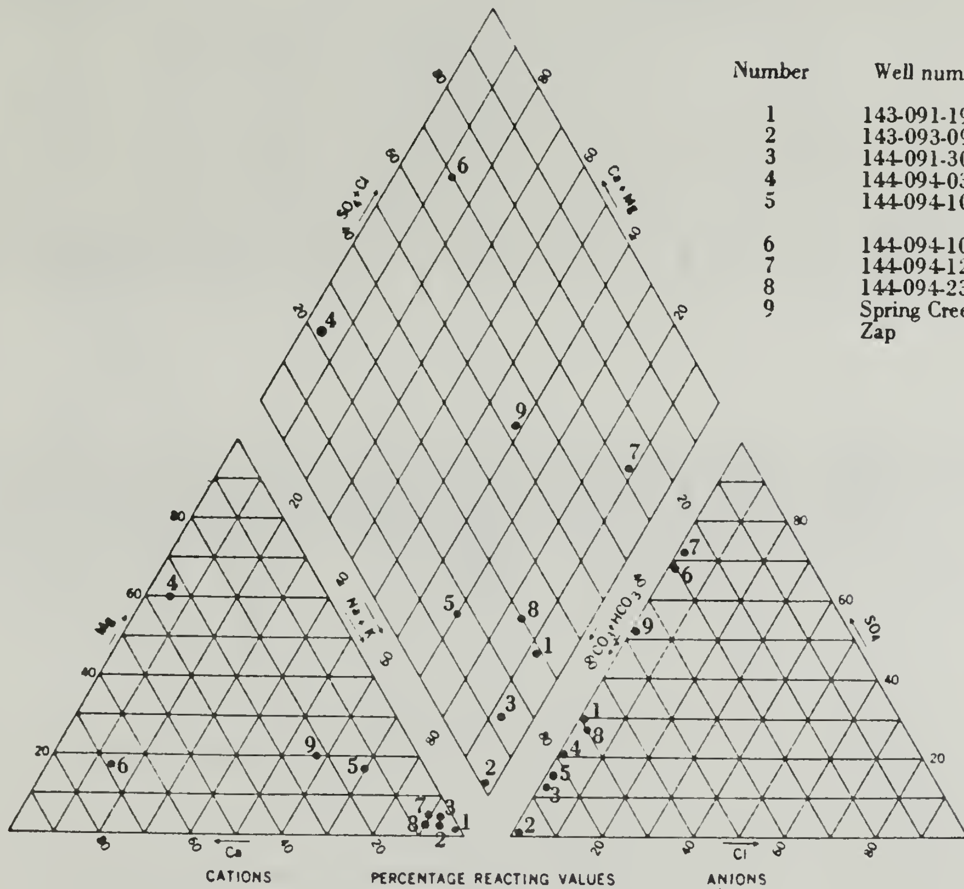


FIGURE 8.--GENERALIZED GEOHYDROLOGIC SECTION NEAR DUNN CENTER SHOWING GROUND-WATER FLOW PATHS



Number	Well number	Depth, in feet below lsd	Dissolved solids (mg/l)
1	143-091-19AAA	670	1830
2	143-093-09BCB	396	1990
3	144-091-30AAA2	512	1580
4	144-094-03CCC	50	245
5	144-094-10DAA1	77	525
6	144-094-10DAA2	60	1696
7	144-094-12CCC	80	3500
8	144-094-23ADD2	260	1792
9	Spring Creek at Zap	Discharge 2.8 ft^3/s	1410

FIGURE 9 —MAJOR CONSTITUENTS IN WATER FROM THE HORSE NOSE BUTTE AREA

TABLE 18 -Stratigraphic and aquifer correlation chart of the Knife River basin

Era	System	Group	Formation/Member	Aquifer
Cenozoic	Quaternary		Alluvium	
			Glacial drift	
	Tertiary		Arikaree White River Golden Valley	
			Fort Union: Sentinel Butte Tongue River	Sentinel Butte Tongue River
			Fort Union: Ludlow	Upper Hell Creek and lower Ludlow
			Fort Union: Cannonball	
Mesozoic	Cretaceous		Hell Creek	Fox Hills and basal Hell Creek
		Montana	Fox Hills	
			Pierre	
		Colorado	Niobrara Carlile Greenhorn Belle Fourche	Undefined aquifers containing saline water
		Dakota	Mowry Newcastle Skull Creek Fall River Lakota	
	Jurassic		Morrison Swift Rierdon Piper	
	Triassic		Spearfish	
Paleozoic	Permian		Minnekahta Opeche	
	Pennsylvanian		Minnelusa	
	Mississippian		Amsden	
		Big Snowy	Heath Otter Kibbey	
		Madison	Charles Mission Canyon Lodgepole Bakken	
	Devonian		Three Forks	
		Saskatchewan	Nisku Duperow	
		Beaverhill Lake	Souris River Dawson Bay	
			Prairie Winnipegosis	
			Ashern	
	Silurian	Interlake	Interlake	
	Ordovician		Stony Mountain Red River Winnipeg	
	Cambrian		Deadwood	

ranged from 245 to 3,500 mg/l, however, water in the samples from the deeper horizons, mainly from the sandstone beds in the lower part of the Tongue River Member, are lower in sulfate, calcium, and magnesium and have a smaller range of dissolved solids. Presumably, sulfate is reduced and calcium and magnesium are replaced by sodium as the water percolates downward.

Water and oxygen moving through the planned spoil banks will react with pyrite present in the lignite to form sulfuric acid, as shown in Figure 10. Because spoil banks are much more porous and permeable than the original overburden, the process after mining will be much more rapid than is presently occurring. The acid formed will immediately react with calcite and dolomite in the aquifer matrix (Figure 7 and Table 19) resulting in water with increased dissolved solids concentration and saturated with calcium-magnesium bicarbonate and calcium-magnesium sulfate.

Much of the clay in the aquifer matrix is montmorillonite (Table 19), which has a high capacity to exchange calcium and magnesium for sodium; therefore, most of the calcium ions in the ground water will be exchanged for sodium ions as shown by soil saturation extracts from spoil banks and the aquifer materials analyzed by Sandoval, and others (1973, p. 12). The extracts were a sodium-sulfate type and had high electrical conductivities.

The water in the shallow aquifers and streams downgradient from the proposed mine area may be expected to increase in dissolved solids concentration within a period of several years after mining begins. The problem is complicated by the fact that the geochemical processes will continue long after mining ceases. The increase in dissolved solids in the water will be mainly the addition of sodium and sulfate ions. Analyses of data from Sandoval and others (1973) and information generated by the computer program WATEQ (Truesdell and Jones, 1974) suggest that the maximum dissolved-solids concentration that will be present downgradient from the mine in the Horse Nose Butte area will be below 6,500 mg/l. In addition, X-ray analyses of the silt and clay (Table 19) indicate that samples from shallow depths in the Horse Nose Butte area contain gypsum. Gypsum is also present in many exposures of weathered lignite examined in the area. Because gypsum is readily soluble, it will be dissolved, carried to the water table, and discharged to nearby streams, mine ponds, and lakes. Much of the calcium will be exchanged for sodium in the process.

At the Horse Nose Butte Study area leachates from spoil banks will migrate downgradient in the shallow ground-water system toward discharge points along Spring Creek (Figure 8) and into the underlying Sentinel Butte and Tongue River Members.

The chemical composition of water in Spring Creek, downstream from the Horse Nose Butte area, varies with discharge. When flow in the stream consists mainly of runoff (Figure 11) during periods of heavy precipitation the dissolved-solids concentration is low. Discharge is low and dissolved-solids concentration high when precipitation and runoff are small such as during late fall and winter. The high dissolved-solids concentration in Spring Creek during periods of low flow is due to a mixture of water discharged from glacial drift and from the Sentinel Butte Member (Figure 8). The water is high in sulfate (Figure 9), dissolved solids, and is chemically similar to shallow ground water from the study area. The drift and alluvial aquifers downstream from the Horse Nose Butte Study Area adjacent to Spring Creek and the Knife River will be little affected by mining because they are discharging into Spring Creek.

Surface-Water Hydrology

The study area lies almost wholly within the Slow Creek drainage basin. The basin has a drainage area of 26.7 mi^2 (69.2 km^2). It is tributary to Spring Creek, which is the largest tributary of the Knife River. Runoff in Slow Creek and its tributaries is intermittent, responding to snowmelt and/or thunderstorms, with short periods of rapid runoff. The main channel slope is about 4.7 ft/mi (0.89 m/km).

Statistical methods based on gaged areas indicate a mean annual flow of 1.3 ft^3/s (0.037 m^3/d) at the mouth of Slow Creek (Crosby, 1970). This indicates, even with total storage, about 1,000 acre-feet/yr (1.2 hm^3/yr) of water would be available for reclamation. It indicates, also, that if internal drainage and storage are established through mining there would be a loss of 1,000 acre-feet/yr (1.2 hm^3/yr) to Spring Creek. This could be about 10 percent of the flow in Spring Creek at the mouth of Slow Creek. Interception of the water in Slow Creek could have a detrimental effect on water quality in Spring Creek because snowmelt and thunderstorm runoff in the Slow Creek basin has a lower total dissolved-solids concentration than the base flow of Spring Creek.

The flood magnitude at the mouth of Slow Creek with a 0.10 probability of being exceeded would be 970 ft^3/s (27.5 m^3/s) and with a 0.02 probability of being exceeded would be 2,100 ft^3/s (59.5 m^3/s; Crosby, 1975). A review of maximum known discharges in relation to drainage area indicates a peak flow of about 35,000 ft^3/s (991 m^3/s), or 1,300 $(ft^3/s)/mi^2$ [14.2 $(m^3/s)/km^2$] for an area the size of the Slow Creek basin. This represents a flood with a probability of being exceeded considerably smaller than 0.01.

Availability of Water for Reclamation

Slow Creek and even Spring Creek would be inadequate sources of water for extensive reclamation. The only reliable surface-water source would be from the Little Missouri River area of Lake Sakakawea about 14 miles (23 km) north.

Small quantities of water are available from the shallow ground-water system in the Dunn Center area; however, this source may be inadequate for extensive reclamation. The Fox Hills and basal Hell Creek aquifer

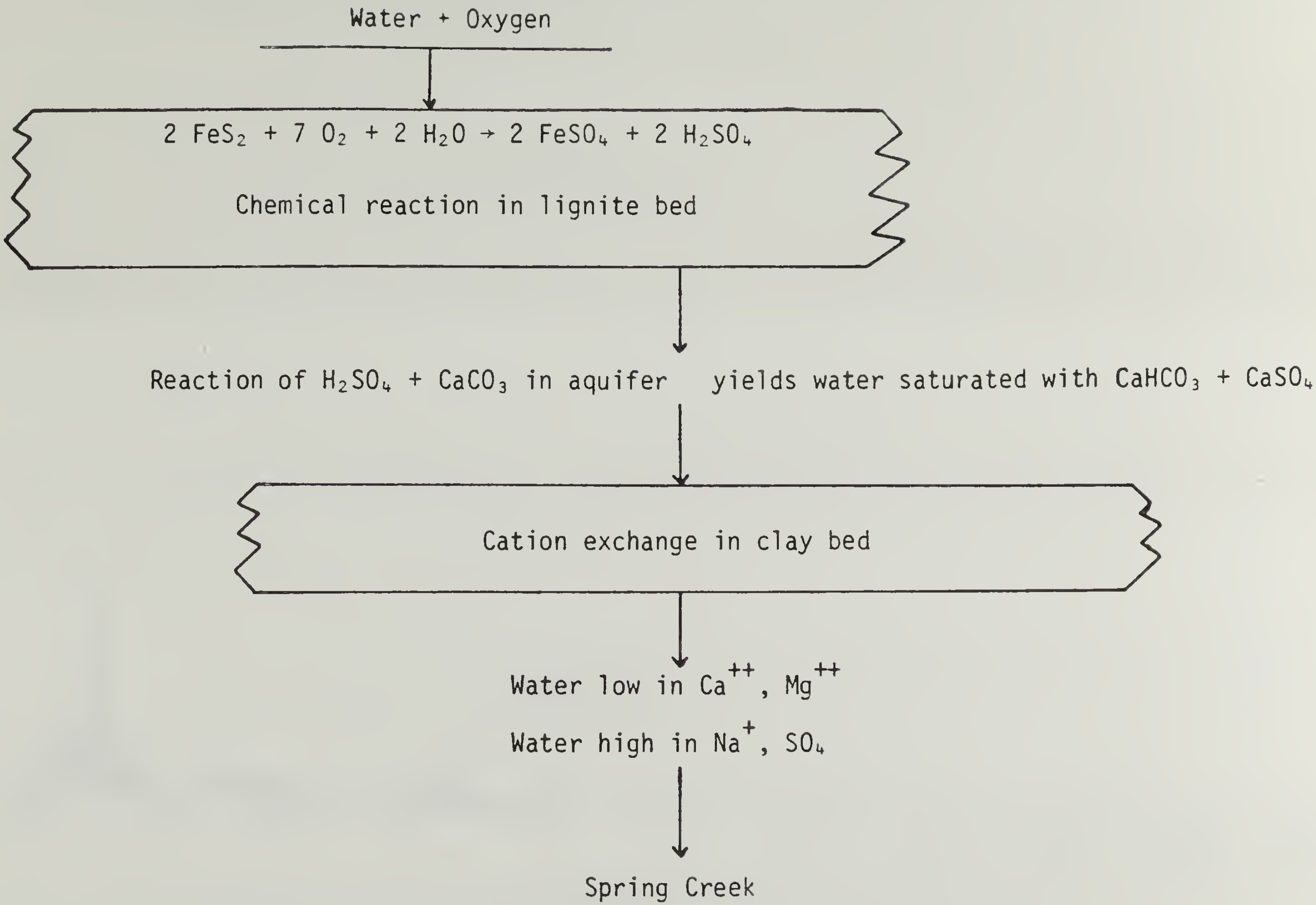


FIGURE 10 -HYPOTHETICAL GEOCHEMICAL REACTIONS IN THE DUNN CENTER AREA

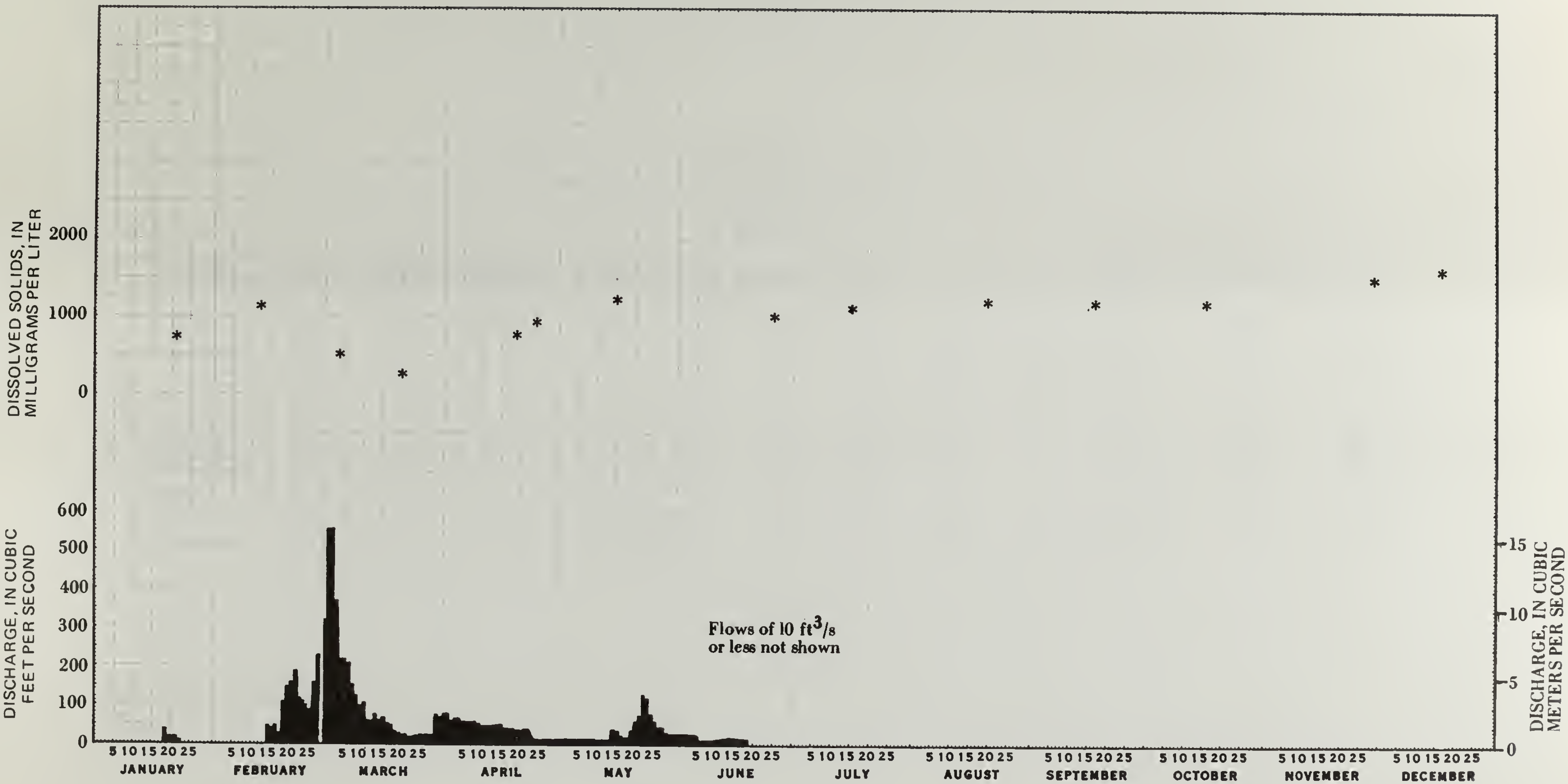


FIGURE 11--DAILY MEAN DISCHARGE AND DISSOLVED SOLIDS OF SPRING CREEK AT ZAP, N. DAK.,1974

Figure 11

TABLE 19-Mineralogy of samples from USBR test well 75-101 (144-094-14DCC)

Weight percent

Depth (feet)	Quartz	Potassium feldspar	Plagioclase feldspar	Calcite	Dolomite	Gypsum	Chlorite	Kaolinite	Illite	Montmo-rillonite	Mixed layer clay minerals	Total
26 - 26.5	36	3	17	0	0	1	<1	9	6	0	17	89
32.7- 33.1	21	3	9	0	0	1	1	11	21	7	22	96
41.1- 46.6	26	3	13	0	0	0	1	6	8	14	21	92
54 - 54.5	21	4	9	0	5	0	2	5	7	36	1	90
84 - 84.5	19	3	7	0	0	0	3	11	17	12	15	87
100.5-101	21	3	9	5	9	0	<1	2	3	30	14	96
120.5-121	27	3	9	5	7	0	<1	3	3	24	19	100
140.0-140.5	33	4	11	3	13	0	<1	3	2	17	19	105
155 -155.5	26	0	0	0	0	0	0	8	9	14	31	88
157	26	2	--	--	--	--	--	9	15	10	29	91
177	44	5	--	--	--	--	--	32	6	7	5	99
186.9-187.2	22	3	7	0	7	0	6	10	14	9	19	97

system may be used as a source of water for small-scale reclamation; however, its use may be limited because of unsuitable quality.

Conclusions

1. The Horse Nose Butte Study area is located in a recharge area for the shallow local ground-water flow system.

2. Ground-water flow from the study area is towards lowland areas along Spring Creek and its tributaries.

3. Due to the low permeability and small thickness of sandstone beds, the study area contains no major shallow aquifers. Fracture zones in the lignite will supply small amounts of water to farm wells, but the lignite beds generally are not significant aquifers.

4. Water and oxygen moving through the planned mine spoil banks will react with pyrite and form sulfuric acid, which will immediately react with calcite and dolomite contained in the aquifer matrix, resulting in a calcium-magnesium sulfate-type water. Generally the dissolved solids concentration will be below 6,500 mg/l. Ion exchange on clay minerals will produce a sodium-sulfate water-type that will move downgradient toward discharge areas.

5. Gypsum present in the spoil banks will be readily dissolved and will cause an increase in the sulfate content in the ground water downgradient from mine sites.

6. Deep aquifers are protected from direct contamination from the mining by the relatively impervious Cannonball Member in the Fort Union Formation and by confining beds in the Hell Creek Formation.

7. Due to the low hydraulic conductivity of the aquifer materials, water-level changes due to strip mining in the Horse Nose Butte area will be limited to an area with a radius of about 1 mile (1.6 km) of the mine site.

8. Short-term geochemical effects will be limited to mine ponds and lakes at the mine site. If these surface-water sources are discharged to tributaries of Spring Creek, an increase in dissolved solids will occur at low flow.

9. The long-term geochemical effect will be an increase in dissolved solids in water from the local flow system downgradient from the mine site.

10. Small quantities of water are available from ground- and surface-water sources in the Dunn Center area; however, the only reliable water source for an extensive reclamation is from the Little Missouri River area of Lake Sakakawea.

VEGETATION, SOIL WATER AND SOIL DETACHABILITY

Vegetation

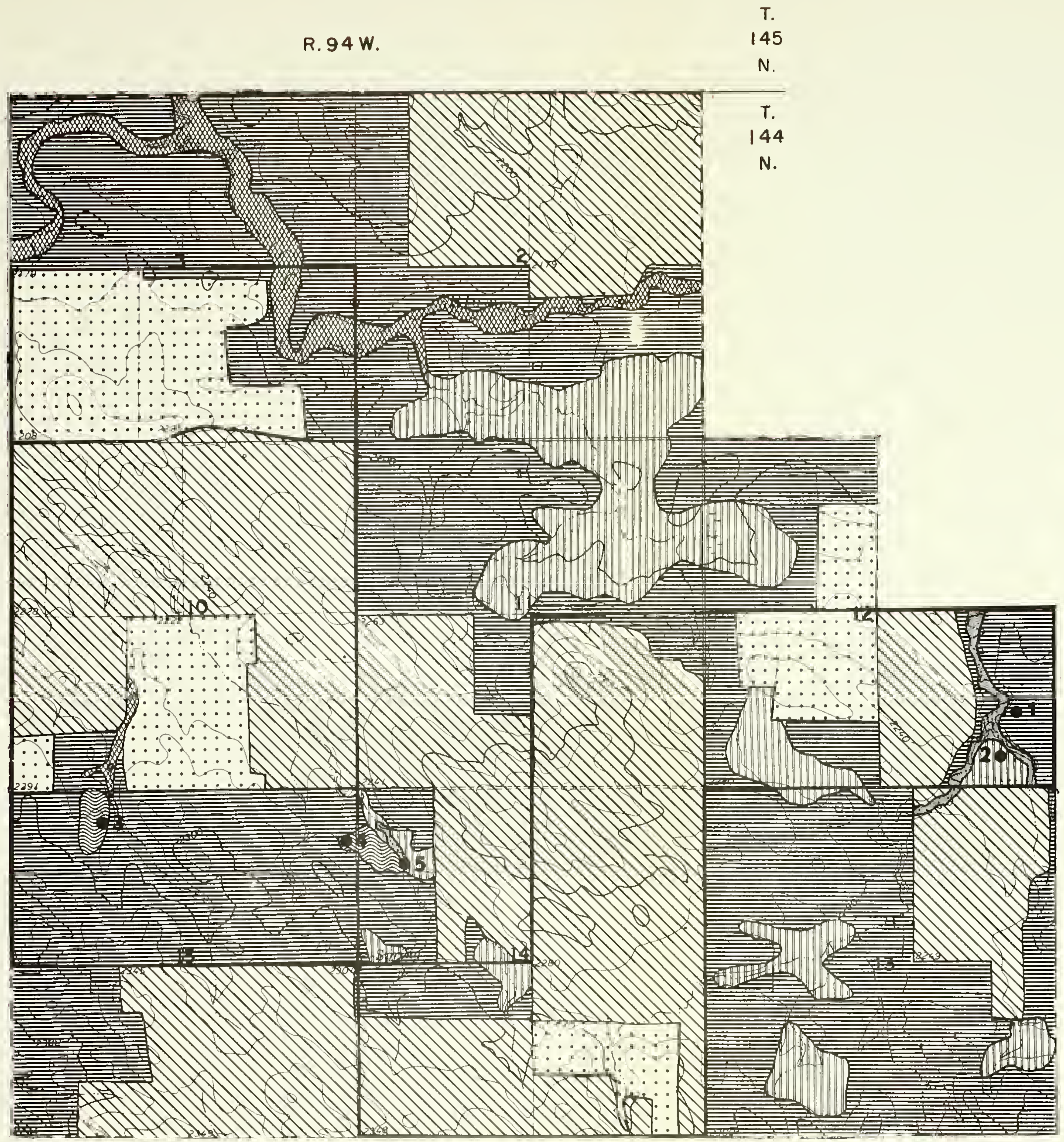
The vegetation as shown on Plate 23 is classified as mixed prairie and has a mixture of mid grasses, short grasses, and some tall grasses. Tall grasses are found only on sandy soils and sites with run-in moisture (Sites 3, 4, and 5 in Table 20). Sloughgrass, little bluestem, and prairie sandreed are the only tall grasses present. Saline lowlands (Sites 2 and 5 in Table 20) typically have mixed stands of western wheatgrass, alkaligrass, sloughgrass, and saltgrass. Medium textured soils of uplands, present on most of the study area, have mixed stands of mid and short grasses. Blue grama is the most abundant short grass but sandberg bluegrass and buffalograss are present in minor amounts. The most abundant mid grasses include western wheatgrass, junegrass, and needle-and-thread. These grasslands are generally in good to excellent condition with little evidence of deterioration due to grazing.

These grasslands are productive and have estimated carrying capacities ranging from 0.7 to 1.8 acres per animal unit month. An estimated 10 sections (6,400 acres) would be required to support a 300 animal unit ranch. Estimated carrying capacities are shown in table 20. They are based on oven-dry yields from two 9.6 ft^2 plots placed at the ends of each 50-foot vegetation transect. A commonly used "rule-of-thumb" considers "proper use" to be 50 percent of the annual production. This figure was adjusted to 40 percent to account for factors such as distance to water and steepness of slope. Additional adjustments were made for species of low palatability.

Soil-Water-Vegetation Relationships

Water relationships in soils associated with native vegetation types that occupy undisturbed parts of the Horse Nose Butte Study Area were defined: first, to identify soil parameters essential to the occurrence of the natural plant communities; and second, to derive useful information for rehabilitation if coal resources are removed by surface mining. Factors affecting the availability of water are primarily responsible for kinds and amounts of vegetation that occur naturally on these rangelands. It is essential to understand these factors if optimum results are to be achieved as a result of rehabilitation efforts. All of the soil moisture and related data collected for this study appear in Appendix D, Table 21.

Seasonal patterns of precipitation influence levels of moisture storage and depletion in soils of the area. Only 28.5 percent of the total precipitation normally falls over the period, October through April, when snow is most likely to accumulate. Average annual



Base from U.S. Geological Survey
Dunn Center East
7½-minute quadrangle

1000 0 1000 2000 FEET

EXPLANATION

Mixed grass. This extensive upland type has mixed stands of mid and short grasses. The most abundant species are western wheatgrass, blue grama, needle-and-thread, and junegrass (site 1, table 20).

Western wheatgrass-alkaligrass. This type is found on moist and salty lowlands. Additional species present are green needlegrass and saltgrass (site 2, table 20).

Prairie sandreed. Other species present in this type include little bluestem, stonyhills muhly, Pennsylvania sedge, and blowout grass (sites 3 and 4, table 20).

Sloughgrass. Well-watered lowlands, mainly in channels, have stands characterized by sloughgrass, saltgrass, fowl bluegrass, and western wheatgrass (site 5, table 20).

Western wheatgrass. Most intermittent stream channels have a cover that is predominantly western wheatgrass.

Haylands.

Cultivated croplands.

● Locations of vegetation and soil sampling sites.

Study area boundary.

VEGETATION MAP OF HORSE NOSE BUTTE STUDY AREA--NORTH DAKOTA, 1975

Table 20

Percent cover of vegetation, mulch, bare soil, and rock; and yields of vegetation and mulch in pounds per acre. Yields are in parentheses.

	Vegetation types	Western wheatgrass-Blue grama		Western wheatgrass-alkaligrass		Little bluestem-Prairie sandreed		Prairie sandreed-Blue grama		Sloughgrass-saltgrass	
	Site numbers.....	1		2		3		4		5	
		Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)	Percent cover	Yield (lb/acre)
Shrubs:											
Artemisia frigida	Fringed sagewort	0.7	(6.0)	1.0	(4.0)	----	(3.0)	----	(59.5)	----	--------
Artemisia tridentata	Big sagebrush	----	--------	----	--------	----	--------	0.3	--------	----	--------
Grasses and grasslikes:											
Agropyron smithii	Western wheatgrass	70.3	(625.0)	40.0	(345.5)	----	--------	----	(3.5)	32.7	(16.5)
Agropyron trachycaulum	Slender wheatgrass	----	--------	----	--------	3.3	--------	----	--------	----	--------
Andropogon scoparius	Little bluestem	----	--------	----	--------	57.0	(379.5)	----	--------	----	--------
Bouteloua gracilis	Blue grama	17.7	(153.0)	6.3	--------	----	--------	6.7	(94.0)	----	--------
Buchloe dactyloides	Buffalograss	----	--------	1.0	--------	----	--------	----	--------	----	--------
Calamovilfa longifolia	Prairie sandreed	----	--------	----	--------	27.0	(393.0)	70.7	(309.5)	----	--------
Carex eleocharis	Needleleaf sedge	----	(1.0)	----	--------	----	--------	----	--------	----	--------
Carex filifolia	Threadleaf sedge	----	--------	----	--------	----	--------	----	(6.5)	----	--------
Carex pennsylvanica	Pennsylvania sedge	----	--------	----	(12.0)	0.7	(73.5)	2.7	(29.0)	----	--------
Distichlis stricta	Saltgrass	----	--------	----	--------	----	--------	----	--------	5.0	(395.5)
Koeleria cristata	Junegrass	2.0	(19.5)	2.7	--------	----	--------	----	(2.0)	----	--------
Muhlenbergia cuspidata	Stonyhills muhly	----	--------	----	(1.0)	0.3	(10.0)	----	(17.5)	----	--------
Poa palustris	Fowl bluegrass	----	--------	----	--------	----	--------	----	--------	20.7	(139.0)
Poa pratensis	Kentucky bluegrass	----	--------	2.3	(15.5)	----	--------	0.3	--------	----	--------
Poa secunda	Sandberg bluegrass	----	(2.0)	----	--------	0.7	--------	----	--------	----	--------
Puccinellia airoides	Alkaligrass	----	--------	13.3	(315.0)	----	--------	----	--------	----	--------
Redfieldia flexuosus	Blowout grass	----	--------	----	--------	0.3	(9.0)	----	--------	----	--------
Spartina pectinata	Sloughgrass	----	--------	----	--------	----	--------	----	--------	35.0	(1,822.0)
Stipa comata	Needle-and-thread	2.3	(105.0)	0.3	(72.0)	----	(4.5)	5.0	(23.0)	----	--------
Stipa viridula	Green needlegrass	----	--------	20.0	(27.0)	----	--------	----	--------	----	--------
Forbs:											
Achillea lanulosa	Yarrow	----	(3.5)	----	(1.0)	----	--------	----	--------	----	--------
Artemisia ludoviciana	Cudweed sagewort	----	--------	2.7	(225.0)	1.3	(44.5)	2.0	(29.0)	----	--------
Aster serecius	Aster	----	--------	----	--------	0.3	(19.5)	----	(1.0)	----	--------
Chrysopsis villosa	Hairy goldaster	----	--------	----	--------	----	--------	----	(5.0)	----	--------
Cirsium undulatum	Prairie thistle	----	--------	----	--------	----	(24.5)	----	--------	----	--------
Echinacea angustifolia	Snakeroot	----	--------	----	--------	1.3	(40.0)	1.3	(72.0)	----	--------
Glychorriza lepidota	Wild lichorice	----	--------	----	--------	----	--------	----	--------	0.3	--------
Hedeoma hispida	Rough penyroyal	2.0	--------	----	--------	----	--------	----	--------	----	--------
Lygodesmia juncea	Skeletonweed	----	--------	0.7	--------	----	--------	----	--------	----	--------
Melilotus officinale	Yellow sweetclover	----	--------	----	--------	----	--------	----	(1.0)	----	--------
Melilotus alba	White sweetclover	----	--------	----	--------	3.7	--------	----	--------	----	--------
Petalostemum pupureum	Purple prairie coneflower	----	--------	----	--------	----	--------	----	(0.5)	----	--------
Plantago purshii	Wooly Indian wheat	----	(3.5)	----	(1.0)	----	--------	----	--------	----	--------
Psoralea argophylla	Silver psoralea	----	--------	----	--------	0.7	(7.5)	0.7	--------	----	--------
Selagenella densa	Clubmoss	----	--------	0.3	--------	----	--------	----	--------	----	--------
Sphaeralcea coccinea	Salmon colored mallow	----	(5.5)	----	--------	----	--------	----	--------	----	--------
Tragopogon pratense	Oyster salsify	1.0	--------	1.7	--------	----	--------	----	--------	----	--------
Unidentified forbs		2.3	(13.0)	----	(5.5)	----	(2.5)	----	--------	----	--------
Mulch		1.7	(645.0)	7.7	(830.5)	3.4	(1,396.5)	9.0	(202.5)	4.3	(1,062.5)
Bare		----	--------	----	--------	----	--------	0.3	--------	2.0	--------
Rock		----	--------	----	--------	----	--------	1.0	--------	----	--------
Total live cover (percent) and total vegetation yields (lb/acre)		98.3	(937.5)	92.3	(1,024.5)	96.6	(1,011.0)	89.7	(653.0)	93.7	(2,373.0)
Estimated carrying capacity in animal unit months per acre			1.8		1.6		1.6		3.7		0.7

precipitation reported for Dunn Center, the nearest station to the site, is 4.14 dm (16.3 in.), so a total of 1.12 dm (4.4 in.) can be assumed to arrive as snow. Snow falling on the area is redistributed by winds. As a result, snow accumulates in low areas and behind obstructions. There is evidence that maximum levels of storage occurring in soils is influenced by quantities of windblown snow that characteristically accumulate. Moisture depletion starts with the initiation of plant growth. Storage is typically maintained at high levels during May, June, and July as a result of frequent rains that yield approximately 2.16 dm (8.5 in.) of water. Maximum levels of storage probably occur at the peak of the rainy season in June. Storage is then depleted to minimum levels during August and September.

Late summer storms occasionally replenish moisture storage to various levels. No storms of any great magnitude occurred during the summer of 1975 before soils associated with vegetation types were sampled in early September. Therefore, minimum levels of storage measured should be indicative of the relative capabilities of vegetation to deplete moisture from soils.

Voids available for infiltration of water to depth in soils are the result of maximum levels of wetting that have been achieved within a period of many years. Void moisture capacity (VMC) values are computed from volume weight (VW) values, assuming that the average specific gravity of soil particles is 2.65 g/cm^3. The mathematical relationship used is: $VMC = {}^1/VW - {}^1/2.65$. Differences in maximum levels of wetting achieved with increasing depth are interpreted from void moisture-capacity values.

Moisture-retention capability (MRC) values indicate quantities of water adsorbed to surfaces of soil particles. Moisture-retention capability (MRC) is the water content of the soil when the adsorptive force exerted on the water by the soil particles is 220 gm/cm^2 (.22 bar.). The concept of moisture-retention capacity is similar to that of "field capacity" in that drainage is practically ceased at this retention force, but moisture-retention capability is more specific because it is based on the amount of adsorptive surface in a soil. There is evidence that 10 molecular layers of water are adsorbed (Michurin and Lytayev, 1967) at the moisture-retention capability level (see Figure 12). Under conditions where the moisture content is less than the moisture-retention capability, water is retained only as adsorbed films, with each film being one molecule thick.

If drainage is impeded, water accumulates in soil, first, as adsorbed films up to a maximum of 16 molecular layers. Water then accumulates as capillary water on top of the adsorbed water until the soil becomes saturated (see Figure 12). After recharge ceases, capillary water drains slowly to depth, then the outer six layers of adsorbed water, which are held by small retention forces, also drain, and the remaining water is held at the moisture-retention capability level.

Water retained by capillary forces can be present to a maximum of 222 cm above a water table or a saturated zone above an impermeable layer. The maximum retention force is $10^{2.34}$ or 222 g/cm^2. For each centimeter in height above the water table, the retention force increases 1 g/cm^2. Ten molecular layers of water are adsorbed to particle surfaces at the limit of capillary rise; 16 molecular layers of water are adsorbed beneath water retained by capillary forces 1 cm above the water table.

The moisture-retention force increases 2.46 times as each of the 16 molecular layers adsorbed to the surface of soil particles is desorbed (removed). The retention force is 1 g/cm^2 when 16 molecular layers are adsorbed increasing to 2.46 g/cm^2 when 15 molecular layers remain adsorbed. The retention force progressively increases to 6.05, 14.89, 36.64, 90.2 and 222 g/cm^2 as the surface of the fourteenth through tenth molecular layers of adsorbed water are exposed. The magnitude of the last increase in sorption force explains why the tendency for water to drain to depth decreases drastically at the moisture-retention capability level.

The fact that the sorption force increases 2.46 times as each consecutive molecular layer of water is desorbed means that the increase in force is proportional or exponential. The exponent or logarithm of the sorption force expressed in g/cm^2 increases by uniform increments of 0.39 as each consecutive molecular layer of water is desorbed (see Figure 12). Expressed exponentially the sorption force increases progressively from 10^0 to $10^{0.39}$ to $10^{0.78}$ to $10^{1.17}$ to $10^{1.56}$ to $10^{1.95}$ to $10^{2.34}$ as each consecutive molecular layer of water drains off until ten molecular layers of water remain adsorbed at the moisture-retention capability level.

Moisture-retention forces existing at the time soils were sampled were measured using the wide range "filter paper" method of McQueen and Miller (1968). The retention force or moisture stress is determined from the moisture content of standard filter papers when they are at moisture equilibrium with the soil.

Moisture contents of soils from saturation to oven dryness and the related retention forces can be computed, if the stress at any level where between 3 and 10 molecular layers are adsorbed has been measured, using the graphic modeling technique of McQueen and Miller (1974).

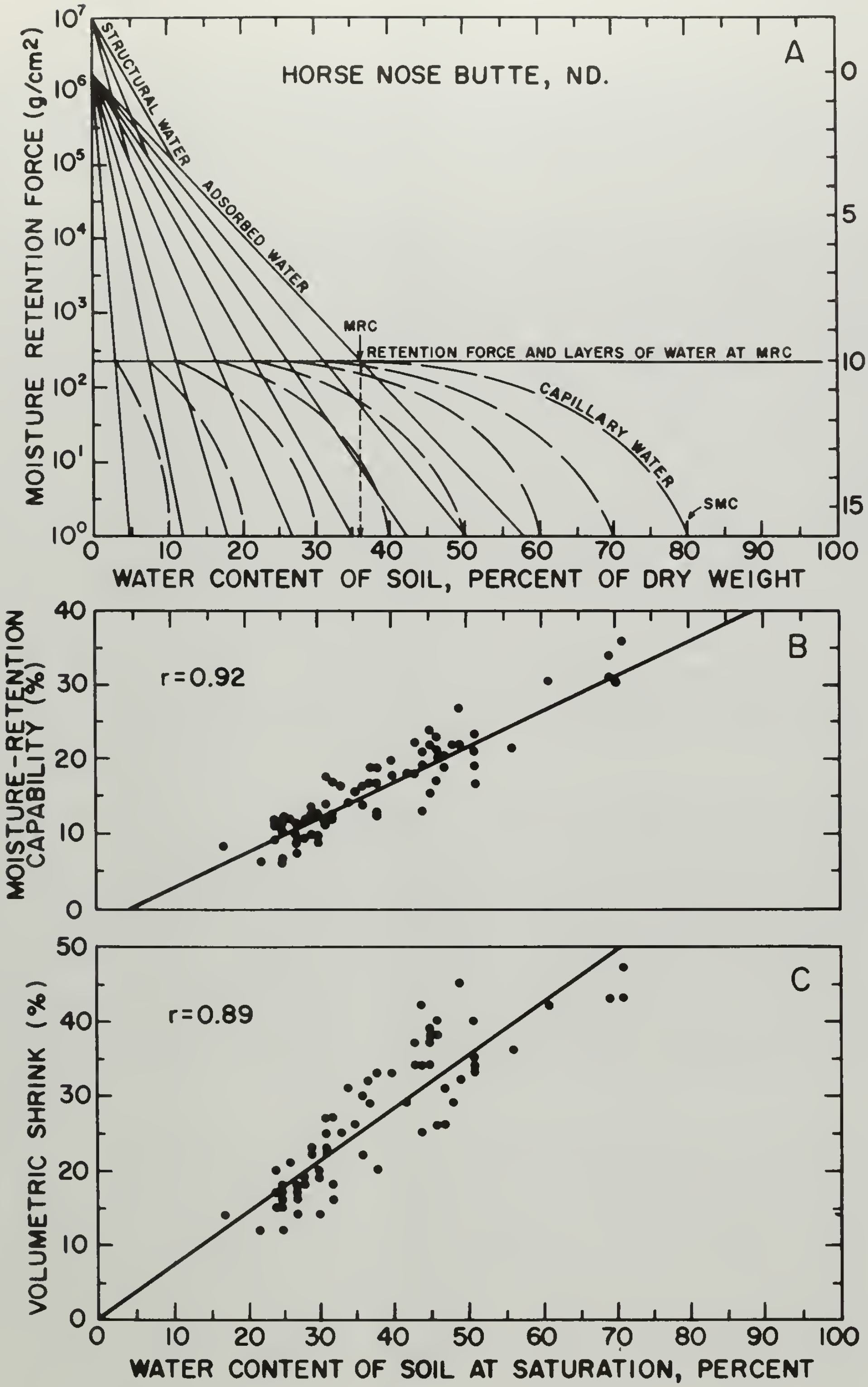


Figure 12 —Graphic model showing relationships between moisture content and moisture-retention force for soils with different moisture-retention capabilities (MRC) and saturation-moisture capacities (SMC). Soil-water relationships used to define the model are shown in parts B and C.

Quantities of capillary water in excess of adsorbed water can also be approximated if the saturation moisture capacity is measured. Criteria for saturating soils, prescribed by Richards and others (1954) were used in this study.

Moisture-retention characteristics of soils with saturation-moisture-capacity (SMC) values of 10, 20, 30, 40, 50, 60, 70, and 80 percent are illustrated in Figure 12. Saturation-moisture-capacity and moisture-retention capability values used to define these lines were derived from the relationship illustrated in Figure 12. Lines representing adsorbed moisture were extended down from $10^{6.25}$ on the vertical axis through points defined by the moisture-retention force of $10^{2.34}$ g/cm^2 and the water content at the moisture-retention capability of each soil. These lines represent variations in moisture-retention force with variations in moisture contents in the soils. Assuming a change of 0.39 in the exponential value of the force for each layer of water, the number of molecular layers adsorbed to particle surfaces can be discerned (see Figure 12). Variations in moisture contents as capillary forces decrease from the moisture retention capability level to saturation were approximated by sketching in lines, as illustrated, using a french curve. Quantities of capillary water can vary between the lines representing adsorbed and capillary water (Figure 12). The curved lines represent maximum probable quantities that can be retained by capillary forces.

Soils contain an extra increment of water retained at high levels of stress. This water is contained within the structure of clays, and is, therefore, defined as structural water. Quantities of structural water are approximated by extending lines down from $10^{7.00}$ on the vertical axis to the point representing moisture content at a retention force of $10^{5.00}$ g/cm^2 on lines representing adsorbed water (Figure 12). As soils dry the water contained within the structure of clays can be depleted. This water must be replenished when soils are rewetted. If this increment of water is not considered in computations, the computations will be slightly in error.

Linear relationships between water content of soil at saturation and moisture retention capability (MRC) used to define the graphic model in Figure 12 are presented in Figure 12. The data also permitted definition of a single linear relationship between water control at saturation and volumetric shrink, which is illustrated in Figure 12. Soils in the area have relatively high swell-shrink capabilities. This is reflected in the model (Figure 12) by the progressive increase in capillary water capacity relative to the adsorption capacity as the retention capabilities of the soils increase. Capillary water content is a maximum at saturation, which is an index of maximum void-moisture capacity.

Under field conditions it may not be practical to directly define the moisture-retention capability of soils from moisture content and moisture stress data as prescribed by Miller and McQueen (1974). Because of this, an indirect field method has been devised which does not require drying of the soil. Soil sampled at field moisture content can be saturated and its saturation-moisture content determined from the weight per unit volume of the saturated soil as illustrated in Figure 13. The relationship in Figure 13 and the relationship between moisture content at saturation and moisture-retention capability in Figure 12 can be combined to permit approximation of moisture-retention capability from weight per unit volume of saturated soil, as is illustrated in Figure 13.

Site Studies

Five distinct types of native vegetation were recognized on the study area and representative sites were selected for sampling the vegetation and the soils. All of the soils data collected at these sites are presented in Table 22.

The amounts of moisture that can be stored in the profiles between moisture-retention capability (MRC) levels and minimum levels of storage in September 1975 were computed (see Figure 14). This so-called "rechargeable-moisture capacity" is not necessarily even proportional to the quantity of water available to plants from a given soil. In the upper parts of the soil profiles where void-moisture capacities exceed moisture-retention capabilities, computed rechargeable-moisture capacities could logically be exceeded for periods of time. Moisture present in this portion of the voids would subsequently drain to depth or be evapotranspired in place. Plants would have to exert less energy per unit of water adsorbed to use water in excess of retention capability as compared to periods where soil moisture storage is depleted below moisture-retention capability levels. Ready availability of water at minimal energy levels during the spring rainy period is probably why grasses predominate in this climate region. This is also the reason why native vegetation has been replaced by cultivated crops on the better drained soils in the area.

The little bluestem-prairie sandreed type (Site 3, Plate 23, Table 20 and Figure 14) occurs on the tops of hills where medium- to fine-textured soil is underlain by finer materials, that apparently impede drainage. Accumulations of water above the impeding material and subsequent dryings have apparently resulted in voids capable of holding 2.7 dm of water (Figure 14). Thus, there is evidence that water is retained, at least temporarily, at levels of stress less than $10^{2.34}$ or 222 g/cm^2. The 1.27 dm (.20 + .85 + .22) of water depleted between

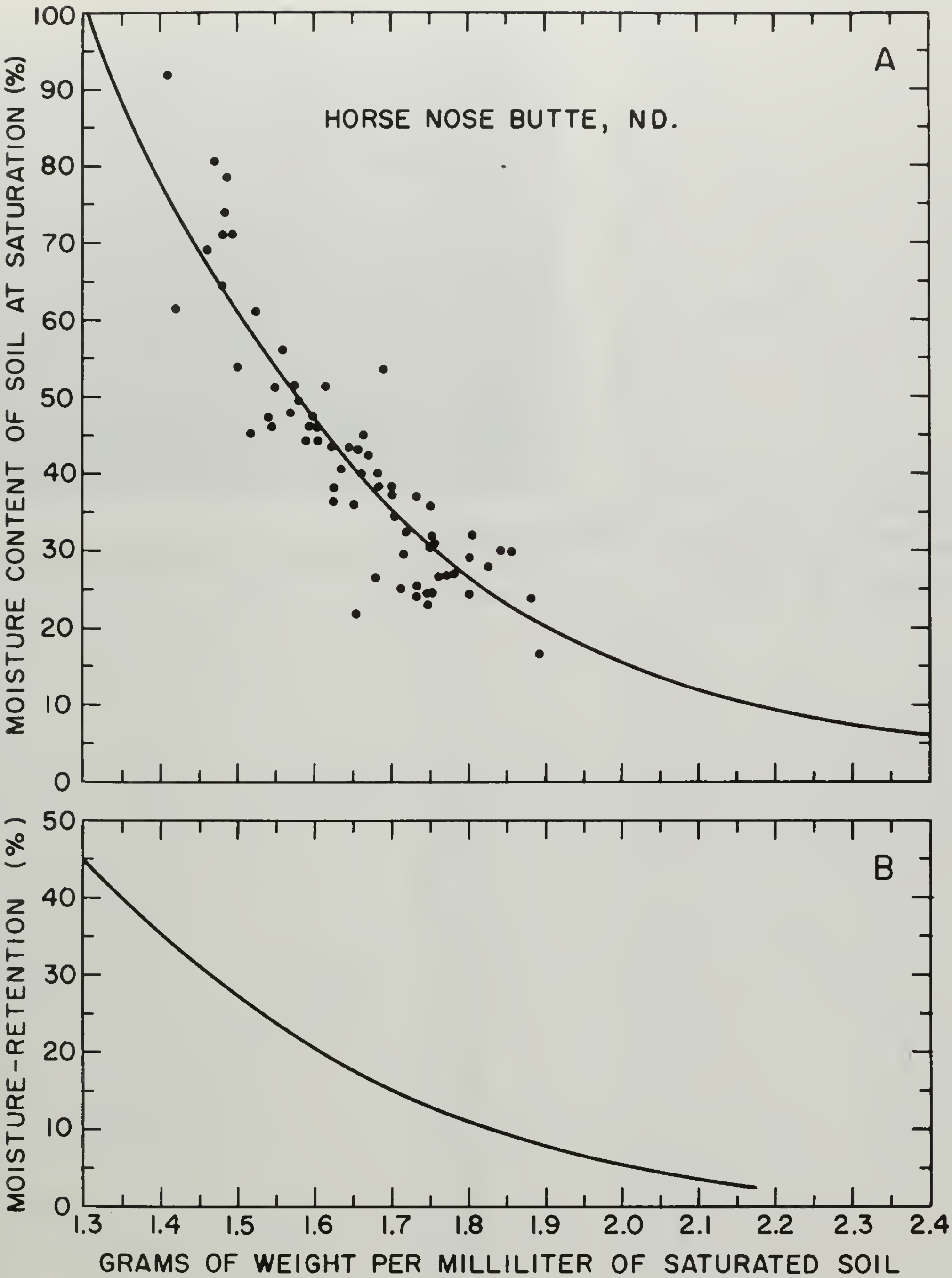


Figure 13 --Relationships for determining the moisture content at saturation and the moisture-retention capability of soil from the weight of a known volume of saturated soil.

Figure 14

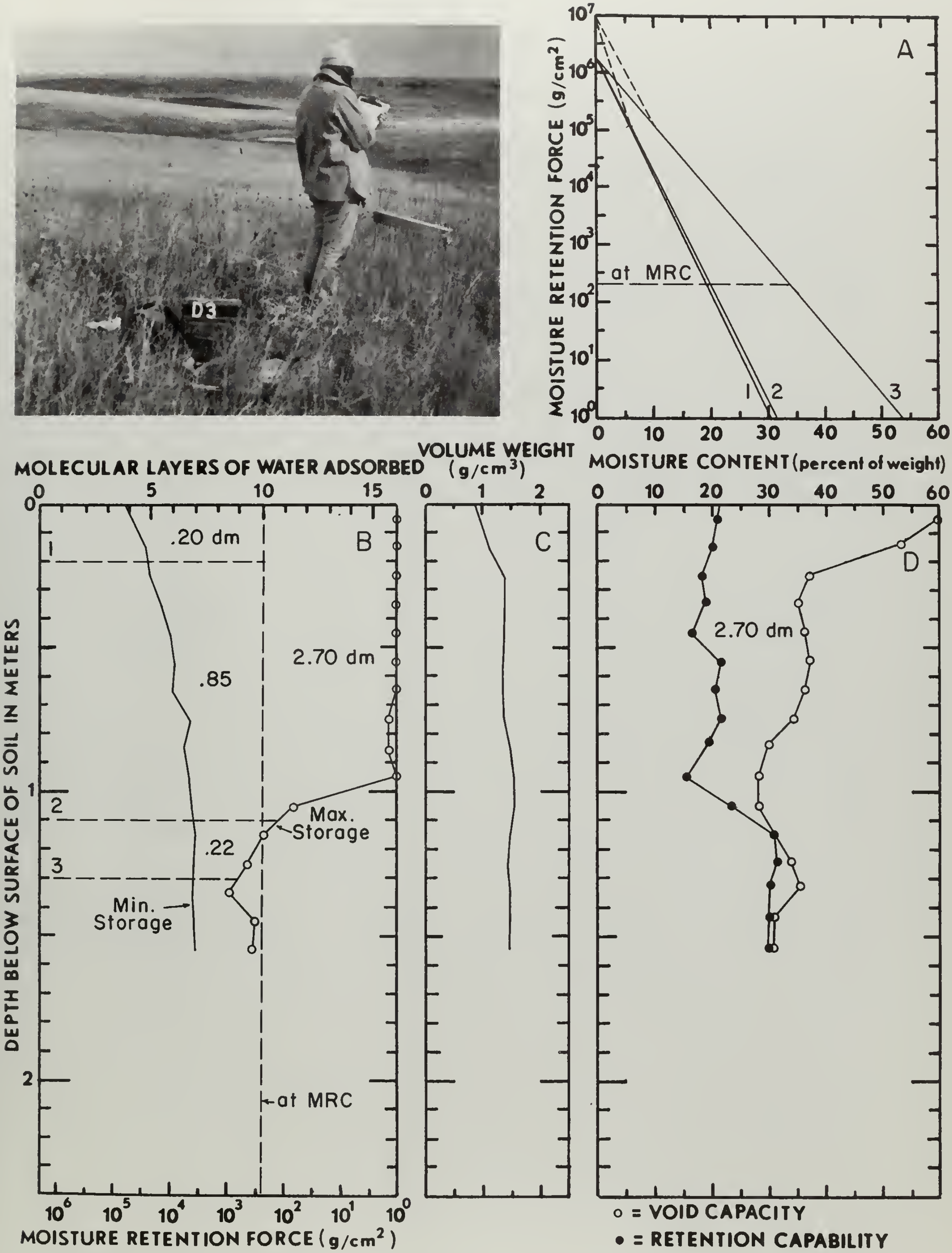


Figure 14.--Soil-water and related properties of an upland site in the little bluestem and prairie sandreed type (site 3, plate 23).

Table 22 --Ranges of tolerances of species and the diversity of vegetation as affected by maximum soil moisture-retention force
X indicates presence of a species

Grasses and Sedges	Site 1	Site 4	Site 3	Site 5	Site 2
Sandberg bluegrass	X	—	X		
Blue grama	X	X	—	—	X
Junegrass	X	X	—	—	X
Western wheatgrass	X	X	—	X	X
Needle-and-thread	X	X	X	—	X
Prairie sandreed		X	X		
Stonyhills muhly		X	X	—	X
Threadleaf sedge		X			
Pennsylvania sedge		X	X	—	X
Slender wheatgrass			X		
Little bluestem			X		
Blowout grass			X		
Saltgrass				X	
Fowl bluegrass				X	
Sloughgrass				X	
Kentucky bluegrass					X
Alkaligrass					X
Green needlegrass					X
Maximum moisture-retention force (g/cm^2)	$10^{4.57}$	$10^{4.20}$	$10^{3.91}$	$10^{3.81}$	$10^{2.61}$

moisture-retention capability levels and minimum levels of storage in Figure 14, therefore, is an underestimate of the amount of water that can be stored in this soil before runoff occurs. Tall grasses like little bluestem and prairie sandreed probably occur here because considerable water is available at low moisture-retention levels during the major growth period.

A maximum of 3.97 dm (2.70 + 1.27) can enter the soil between minimum levels of storage measured and complete saturation of voids. This is approximately equal to the average annual precipitation of about 16 inches. Normally not enough precipitation will have arrived by the end of June to fill all of the voids. Normal depletion by evapotranspiration could easily prevent enough moisture accumulating even in wetter years to result in much runoff. Exceptionally heavy storms, however, could exceed the infiltration rate and result in runoff.

The prairie sandreed-blue grama type (Site 4, Plate 23, Table 20 and Figure 15) also occurs on hilltops. Moisture-retention capabilities of the surface materials are similar to those at Site 3. There is less impedance to drainage in this soil, so more water penetrates to horizon 3 and the subsoil. This results in storage at moisture-retention capability even at 14 dm deep (Figure 15). Vegetation must, therefore, exert more energy to desorb water than in the previous soil where "perched" water is available at lower levels of moisture sorption force. This no doubt accounts for the presence of blue grama, a short grass, with prairie sandreed. On the basis of decreases in moisture stress with increasing depth, it can be assumed that blue grama depleted moisture from the surface soil, while prairie sandreed obtains moisture mostly at greater depth where it is available at lower levels of stress. Water retained at moisture-retention-capability levels was still present at the base of the profile near the end of the growth period (Figure 15).

Comparison of data derived from the two sites indicates that productivity could be increased by replacing soil materials in a manner that results in "perching" of water in the upper meter (40 in.) of soil. A yield of 1,011 lb/acre was derived where "perched" water was utilized (Site 3) as compared to 653 lb/acre at this site where drainage to depth and storage at moisture-retention-capability levels occurred.

A total of 3.25 dm (1.53 + 1.72) of water is capable of being stored in this soil, between minimum levels of moisture storage and void moisture capacity (Figure 15). It is not likely that runoff will occur from soils associated with this community under normal precipitation conditions. Runoff could occur if more than 1.72 dm (6.77 in.) fell in a short period of time in June when moisture-retention-capability levels are probably achieved at all depths in this soil.

The western wheatgrass-blue grama type (Site 1, Plate 23, Table 20 and Figure 16) covers large portions of the uplands with coarse- to medium-textured soils. Apparently, large areas formerly occupied by this type are now under cultivation. Voids capable of holding more water than can be retained at moisture-retention-capability levels are present in the upper 7 dm of soil (Figure 16). At least 1.97 dm (7.75 in.) would be required to saturate the void space that is in excess of retention capability levels. An exceptional storm would be required to produce runoff from lands having this native cover.

Here, as at Site 3, finer material occurs beneath coarser surface soils. The large volume of voids in this surface soil indicates that "perched" water is, on occasion, present in this soil. The beneficial influence of "perched" water on the force required to remove water is reflected by the fact that yields of 937.5 lb/acre were achieved. If this land is disturbed for mining purposes, it will be essential to replace materials in the same order they were removed if the benefits of temporarily "perched" water are to be derived. This soil, however, does not get as wet below depths of 7 dm as soils at the other four sampling sites. Also, the mid and short grasses of this site have more completely depleted moisture stored in the soil (Figure 16) than tall grasses were capable of doing in the zones of the other soils where their roots predominated. Because with their greater ability to desorb moisture to higher levels of moisture-retention force, they should be able to withstand drought better than tall grasses.

The sloughgrass-saltgrass type (Site 5, Plate 23, Table 20 and Figure 17) occurs in drainageways that carry runoff from the uplands. This type is of minor importance in the area. Void-moisture capacities closely approximate moisture-retention capabilities throughout the soil. This is probably the result of "slacking" action, causing particles to settle closer together, as a result of prolonged flows of water. As a result, there is little space for air after moisture-retention capability levels have been achieved. This could be the reason why marsh vegetation tends to predominate in this type. Water is stored at moisture-retention capability levels even at depths below 11 dm. These reserves of moisture could be used by vegetation during drought periods. Mid grasses present in this type could probably survive best under drought conditions.

The western wheatgrass-alkaligrass type (Site 2, Plate 23, Table 20 and Figure 18) predominates on wide relatively flat lowlands that are drained by shallow channels. These areas are characterized by the presence of a water table. At the site sampled there was evidence that the free water surface approaches close enough to the surface for water

Figure 15

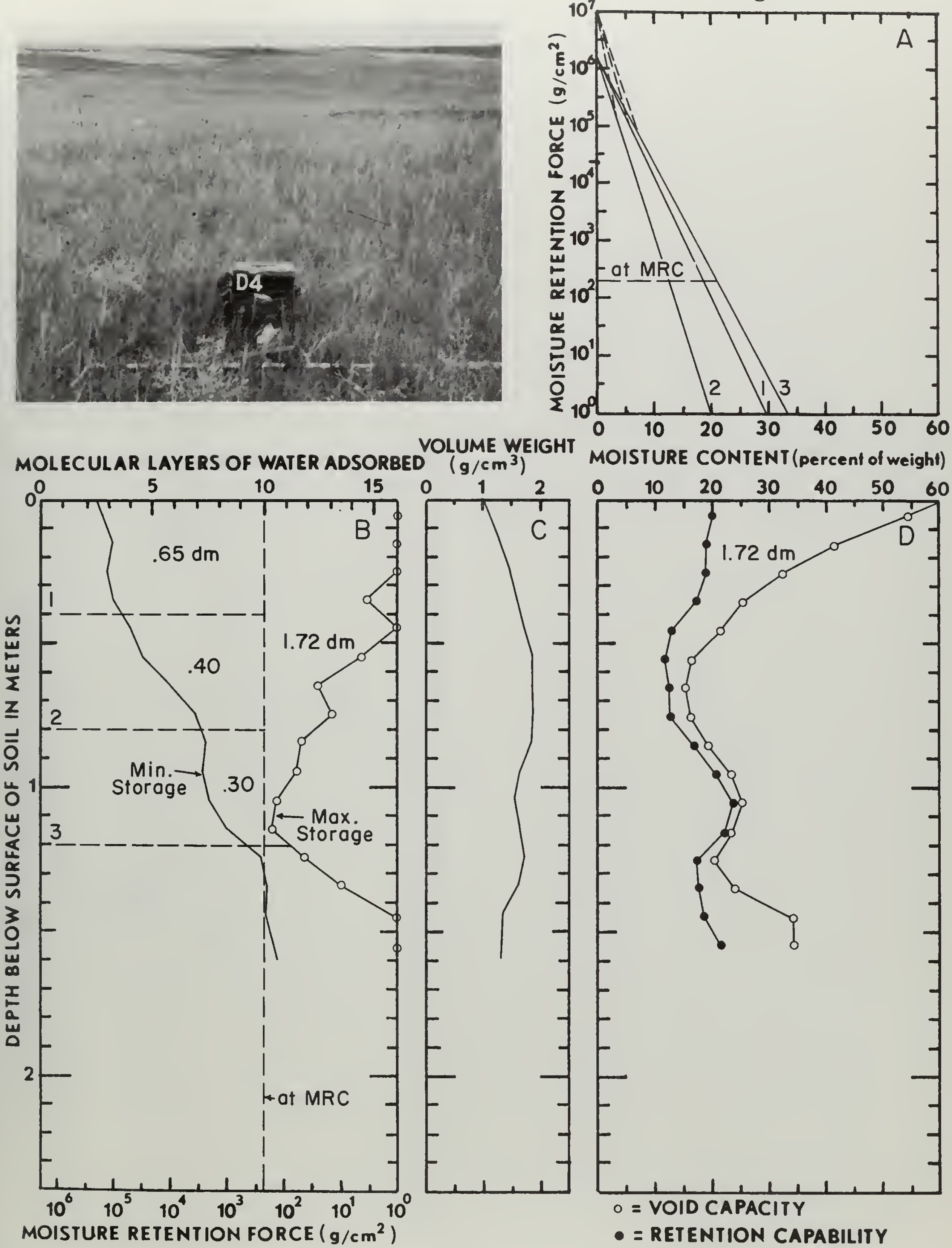


Figure 15.--Soil-water and related properties of an upland site in the prairie sandreed and blue grama type (site 4, plate 23).

Figure 16

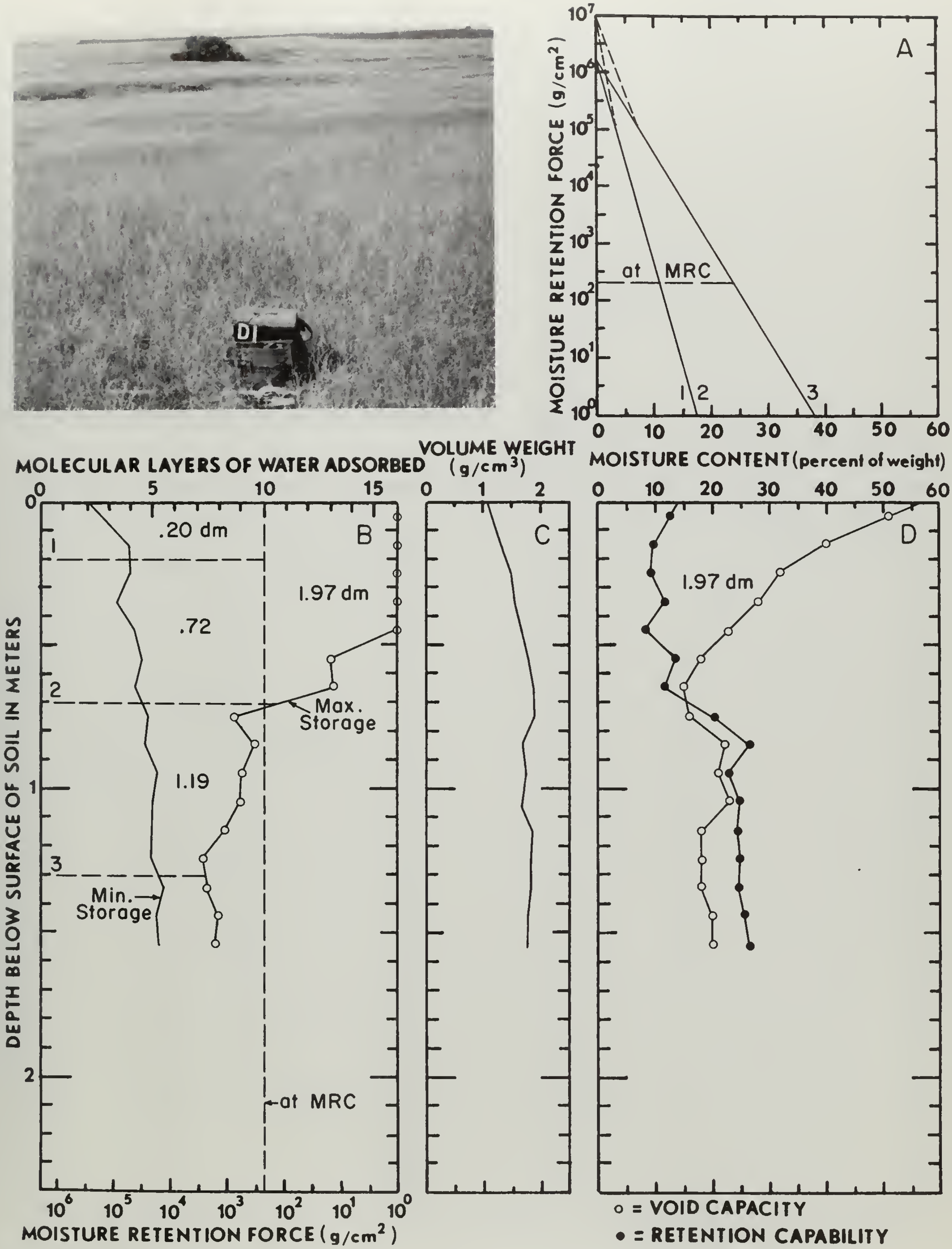


Figure 16.--Soil-water and related properties of an upland site in the western wheatgrass and blue grama type (site], plate 23).

Figure 17

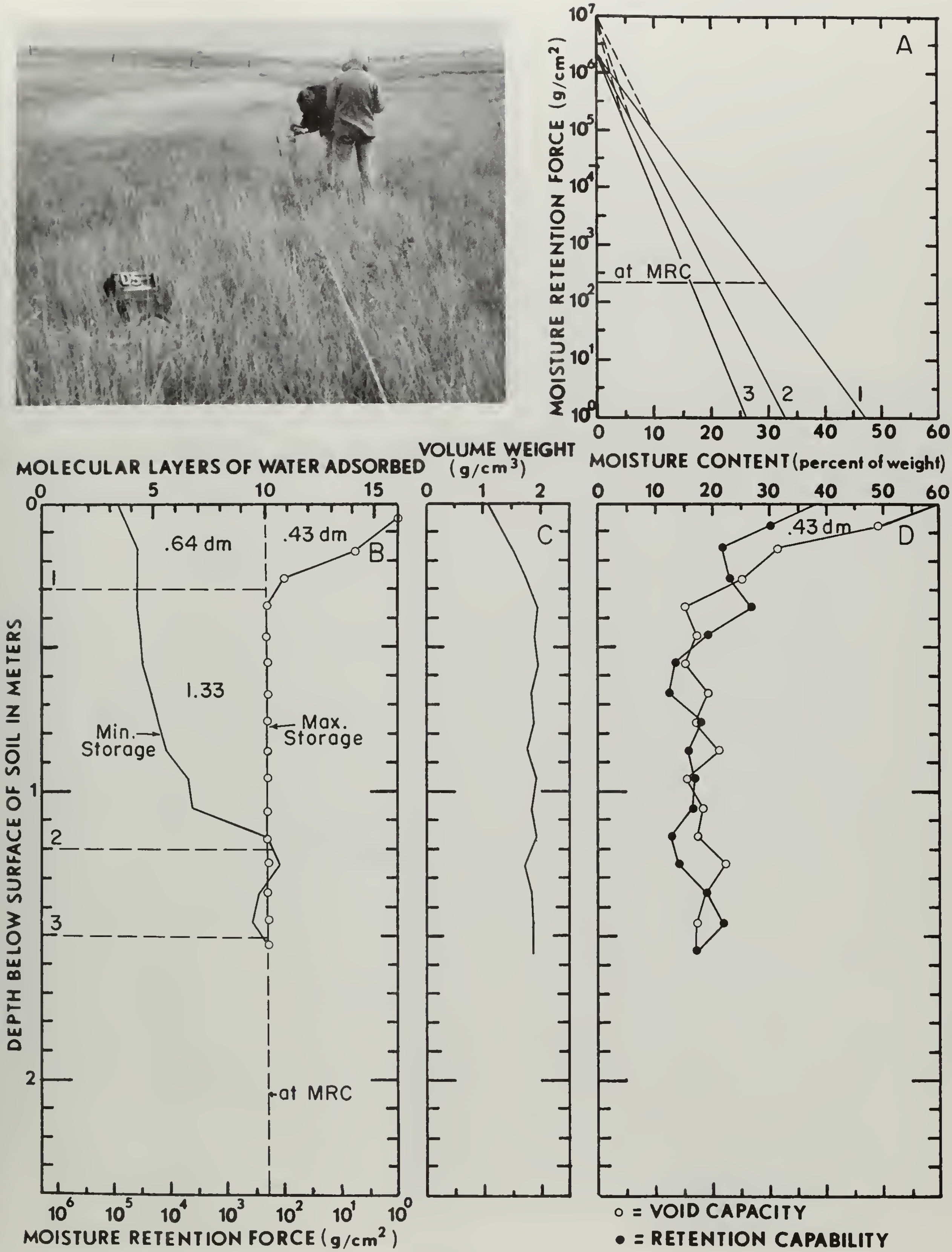


Figure 17.--Soil-water and related properties of a site in a drainageway where the cover is sloughgrass and saltgrass (site 5, plate 23).

Figure 18

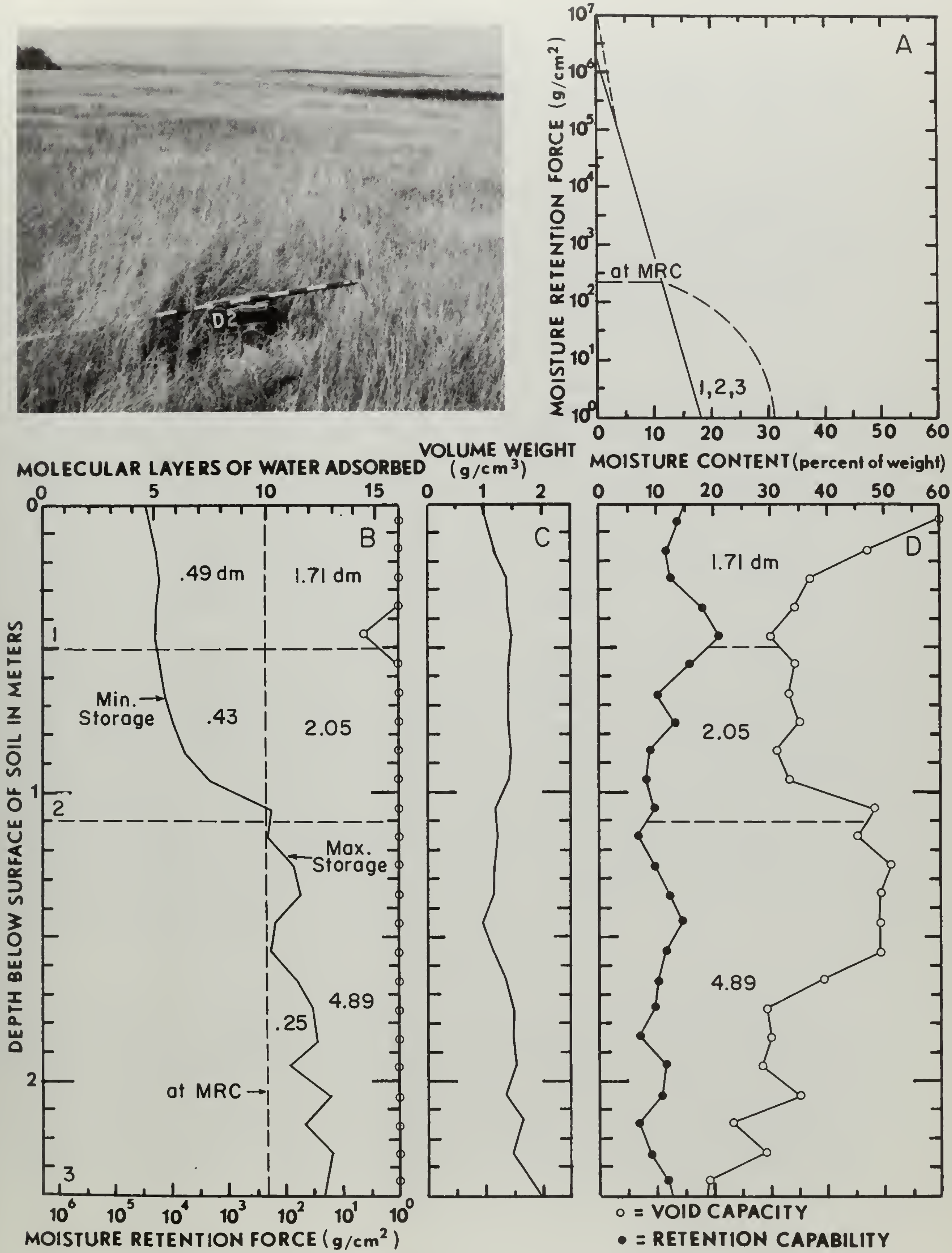


Figure 18.--Soil-water and related properties of a lowland site, underlain by a water table, in the western wheatgrass and alkaligrass type (site 2, plate 23).

rising from it by capillary action to moisten the surface. The large proportion of voids provides evidence that the whole soil column may become saturated in wet years. These wet areas are used primarily for pasture.

If improved drainage to depth results from the disturbance caused by mining, these wetlands could be drained. Under these conditions mid grasses and short grasses that occur within the type would probably survive. Drainage would also make these lands available for crop production. The coarse- to medium-textured alluvium stored in these bottom areas could be used beneficially as topdressing over finer materials if the benefits of "perched" water are desired.

The maximum soil moisture-retention forces shown at the bottom of Table 22 are profile averages obtained by sampling near the end of the growing season when most of the soil moisture was depleted. The data show that the seven species at the top of the list can survive over a wide range of maximum-moisture retention forces. These species normally occur on uplands in semiarid areas. The six grasses at the bottom of the list are normally found on moist lowland areas. The data also show that there is a progressive blending (increasing diversity) of the semiarid upland species and moist lowland species as the moisture-retention-force values decrease.

Several conclusions can be drawn from the data in Table 22 with reference to adopted species for rehabilitating mined areas. First, the six grasses at the top of the list are more drought tolerant than the other species and are more suitable for use on upland areas. Second, these same species occur on moist lowland areas and could be used along with lowland species, such as the last six species listed, to diversify the vegetation there. The sedges and grasses in the middle of the list (threadleaf sedge through blowout grass) have fairly specific moisture requirements and would only be suitable for seeding upland sites where soil moisture is plentiful, such as on gentle northern slopes or on soils that have coarser material overlying a fine-textured layer that impedes drainage.

Summary and Conclusions

Vegetation in the Horse Nose Butte area is dependent primarily on water from snowpacks in addition to precipitation falling in May, June, and July. All of the soils interact similarly with water, and thus fit a single linear relationship between moisture content at saturation and moisture content at the retention-capability level (Figure 12). This permitted development of a single family of linear relationships between moisture content and moisture-retention force for soils with different saturation moisture capacities (Figure 12). Data obtained from study sites were used to define a linear relationship between weight per unit volume of saturated samples of soil and their moisture content at saturation (Figure 13). The two relationships were combined to permit approximation of moisture-retention capability from the weight per unit volume of saturated soil (Figure 13). This will permit evaluation of moisture-retention capability of soil materials under field conditions.

All the soil materials studied are quite capable of producing a good cover of vegetation. The humic surface soil has greater aggregate stability than subsoil and an established microbiological community which make it the most suitable material for covering the reshaped terrain following mining. Doing that will facilitate resestablishment of voids essential to infiltration and storage of precipitation. There is a tendency for replaced topsoil materials to be compacted, so artificial wetting to reestablish the proper distribution and proportion of voids may be required. This would no doubt happen naturally over a period of a decade, but increased runoff and erosion will result if the required void space is not established by temporary, controlled irrigations or by holding natural precipitation on the surfaces in furrows or pits. Measurements of volume weight can be used to determine if void capacities now present in soils have been reestablished. The volume weight data presented in this report can be used as standards of comparison.

The present hydrologic equilibrium will be reestablished if soils materials are replaced at similar slopes in similar topographic positions from which they were removed. This includes replacing materials in the same order and the same thickness at which they naturally occur. Present mining plans and procedures will not provide this level of stripping, storage and placement control. A minimum of 9 dm or 3 feet of the medium-textured silt loam is required to store normal amounts of winter and spring precipitation under low runoff conditions. A greater depth of soil material would permit storage of greater than average amounts of precipitation when they occur. Creation of sufficient void space by artificial wetting would insure penetration and storage of water from larger than normal storms.

Both upland and moist lowland vegetation species occur on sites where the level of stress required to desorb water is lowest (Sites 2 and 5, Table 22). In other studies in Rocky Mountain States, the stress exerted per unit of water desorbed was less in coarse soils than in finer soils with higher moisture-retention capabilities. Both in this and other investigations less sorption force is required per unit of water desorbed if conditions force water to accumulate in films thicker than the 10 molecular layers associated with the retention-capability level. This could result if the correct amounts of material with low moisture-retention capabilities (less than 20 percent by weight) are replaced over materials with higher moisture-retention capabilities. Relationships presented in this report can be used to determine the required depths of materials.

Greater depths of soil will be required to store water derived from precipitation if agricultural practices involving fallowing are planned after mining and rehabilitation. The depths of soil required will have to be established from evidence obtained on cropped lands by the Bureau of Reclamation and Soil Conservation Service. Under premining conditions, soil horizons may still reflect the influence of natural moisture regimens that dominated the area for thousands of years before modern agricultural practices were introduced to the area. Deeper moisture storage resulting from fallowing should be evident as lower volume weights at greater depths in soils. If adequate volume weight data are not available, such measurements should be made prior to removal of soil materials.

Infiltration and Soil Detachability

Soil erosion and sediment production involve the interaction of two sets of forces. One set of forces, the erosive agents, cannot be forecast for any given time period at a given site except as probabilities based on past records. The other set of forces, the ability of the soil to resist the actions of the erosive agents, can be defined by properly designed laboratory and field tests.

Detachment and transport of sediment in runoff can occur only when the rate of rainfall (or snowmelt) exceeds the rate of infiltration. Therefore, the infiltration rate of the soil becomes a definable parameter of the erosive forces. If infiltration relationships are known, estimates can be made for the magnitude of storm that will produce runoff and erosion.

Infiltration rates on mined areas will be different from rates measured on undisturbed areas under native vegetation. Soil structure and root channels that aid infiltration will be destroyed and porosities of the soils will be reduced because of packing by machinery used to replace and reshape the soils. As new vegetation becomes established during the rehabilitation period, high infiltration rates may gradually be restored.

Disturbed hydraulic conductivities, reported on Plates 27 through 32, approximate the infiltration rates expected during rehabilitation. The mean of these values is 1.96 cm/hr. Therefore, runoff and erosion can be expected from many of the storm events that may occur during rehabilitation. Areal distribution of disturbed hydraulic conductivity classes are shown on Plate 24. These are based on the mean disturbed hydraulic conductivities for 117 soil profiles.

Some form of surface treatment should be applied to retain precipitation where it falls until it can infiltrate into the soil. Contour furrows with check dams such as those produced by the "Arcadia furrower" (Branson, Miller and McQueen, 1966) would be satisfactory as would be gouger pits (Sindelar and others, 1974).

Susceptibility of soils to erosion by flowing water was determined in the laboratory by subjecting samples to controlled erosion forces and measuring the rates of detachment (McQueen, 1961). This procedure does not predict actual sediment production from the wide range of erosion events that occur at a site but it does define relative detachability of individual soil samples. Remolded samples were used in these tests to simulate the condition of the soils after mining. Data for detachability of individual samples from vegetation and soil sampling sites shown on Plate 24 and are included in Table 21 in the appendix.

Detachability of soil particles appears to be influenced by the concentration of humus and roots. Surface soils with high organic matter and root concentrations are less susceptible to erosion than deeper soil horizons (see Figure 19). Soils with shallow organic horizons such as Sites 3 and 4 or with stratified layers of clay and sand such as Site 1 do not show the same pattern of detachability with depth (see Figure 19). The organic surface horizon with low detachability rates is thickest for Site 1, probably because water from upslope that infiltrates the soil is rich in organic substances.

Erosion during reclamation of these lands can be minimized by replacing the soils in topographic locations similar to those before mining with present surface horizon materials on top.

SEDIMENT YIELDS

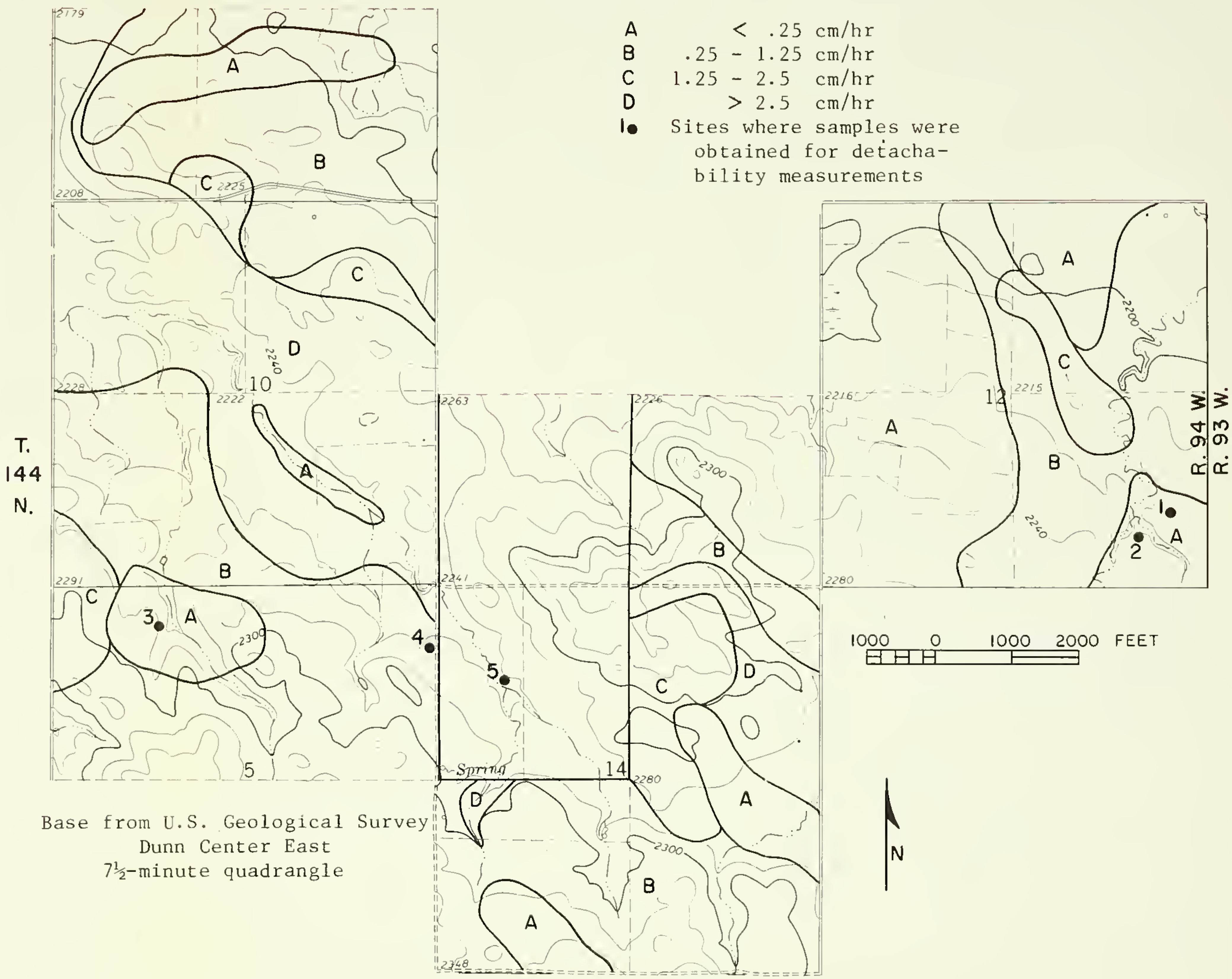
The sediment-yield values presented for this area were derived using a numerical rating method developed by the Pacific Southwest Inter-Agency Committee (PSIAC) (1968) and have been judged to be reasonably accurate but they have not been verified by actual field measurements.

The mapping unit that is the basis of this sediment-yield evaluation is the source area, which is defined as a small relatively homogenous watershed area that is part of a complete drainage basin. Delineations

EXPLANATION

Disturbed Hydraulic Conductivities

A < .25 cm/hr
B .25 - 1.25 cm/hr
C 1.25 - 2.5 cm/hr
D > 2.5 cm/hr
1● Sites where samples were obtained for detachability measurements



Base from U.S. Geological Survey
Dunn Center East
7½-minute quadrangle

MAP SHOWING HYDRAULIC CONDUCTIVITIES OF DISTURBED SOILS ON THE HORSE NOSE BUTTE STUDY AREA--NORTH DAKOTA, 1975

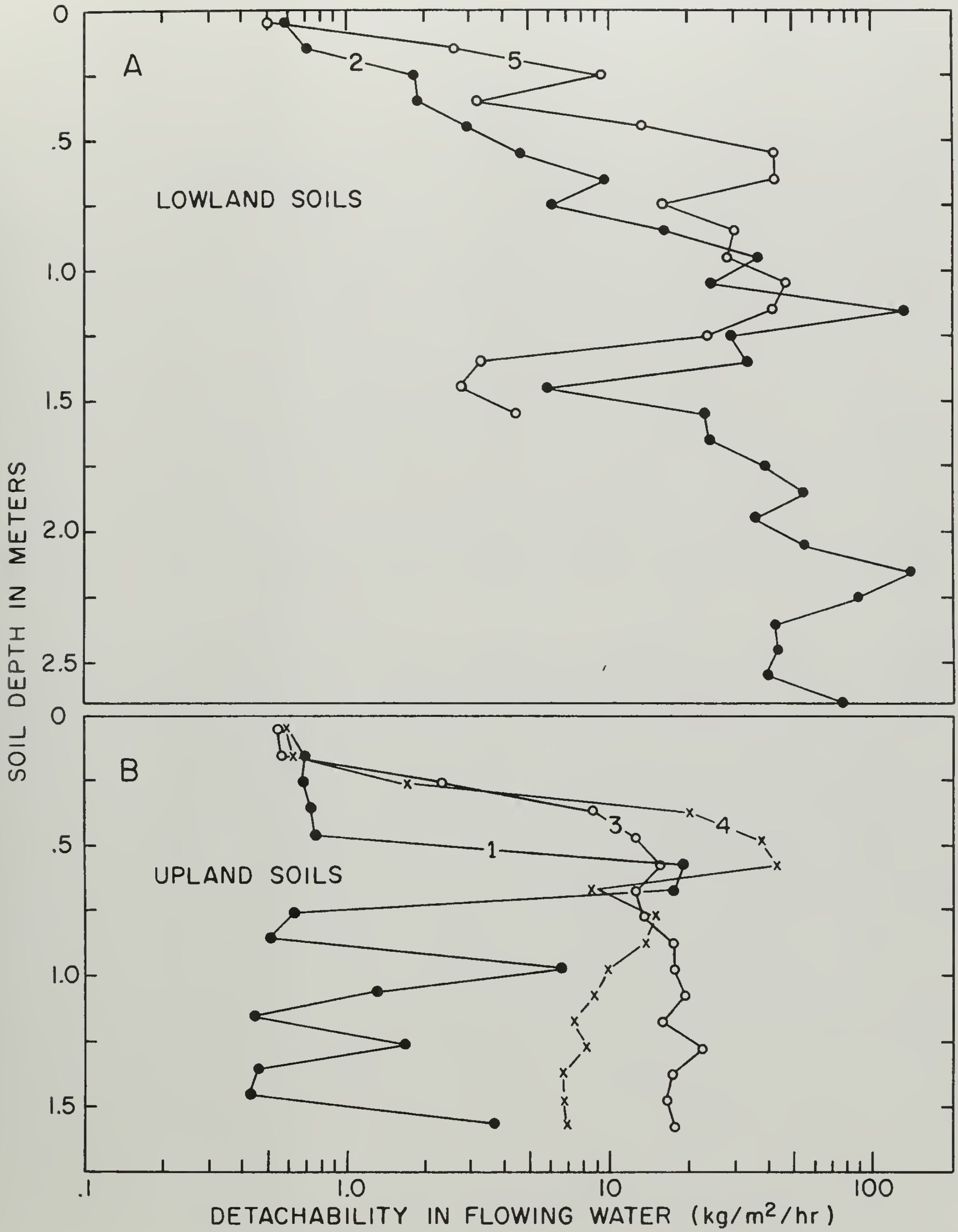


Figure 19.--Changes in soil detachability with depth in the profiles for lowland and upland soils. Locations of the sampling sites are shown on plates 23 and 24.

of the source areas resulted in the map shown on Plate 25. The primary factor used in delineating a source area is landform type. The PSIAC method is used to assess the hydrologic variation of the given landforms as well as to make estimates of sediment yield from them. Numerical ratings are assigned for each of the nine factors of the PSIAC method to representative source areas in accordance with the degree of influence each factor has on the sediment yield from the area. These nine factors are surface geology, soils, climate, runoff, topography, ground cover, land use, upland erosion and channel erosion and sediment transport. The method was developed to make broad sediment yield classifications for large areas, such as river subbasins, but Shown (1970) found that the method provides reasonable estimates for small drainage basins. In applying the method on source-areas, some adjustments in the PSIAC method are made because a complete drainage system is not being considered. Fan and flood plain development are not considered in the topography factor, and sediment transport capabilities are not considered for channels that originate in upslope source areas, that cross through the source area being rated. These factors are taken into account by the sediment conveyance factor (SCF) which is multiplied by the weighted average source-area sediment yield to obtain the sediment yield from a drainage basin.

The scheme used to develop the sediment-conveyance factors was based on one used previously by Frickel, Shown, and Patton (1975). The scheme considers the effects on sediment transport of various conditions such as (1) channel width and gradient, (2) whether the channel is gullied or not, (3) size of the bed material, and type and density of vegetative cover on the channel bed, (4) intermittent gullies in the channel system, (5) evidence of deposition in the channels and the occurrence of alluvial fans, and (6) deposition on bottomlands where flows spread either naturally or because of manmade impoundments or diversions of water. Several of these conditions and drainage basins to which they apply are shown on Plate 26. The primary consideration used in assigning a SCF to a basin, on the study area, was the percent of total channel length that exists as raw gully. Table 23 shows the assigned SCF's and associated basin sediment yield for six basins on the study area. Basin E with no raw gullied channel was assigned a SCF of .5 while Basin D with 26 percent raw gullied channel was assigned a SCF of .9. The SCF's were adjusted downward for Basins A, D, and F in accordance with their sizes because sediment delivery usually decreases as drainage area increases. SCF's vary among the basins but tend to be moderately high. The probable reason for this is that most of the material available for sediment transport is silt and clay which have been detached by raindrop splash.

This fine-grained material is easily transported by minimal flows. It should be emphasized that the SCF's assigned to these basins are site specific and extreme caution should be used if the SCF values are extrapolated from this site.

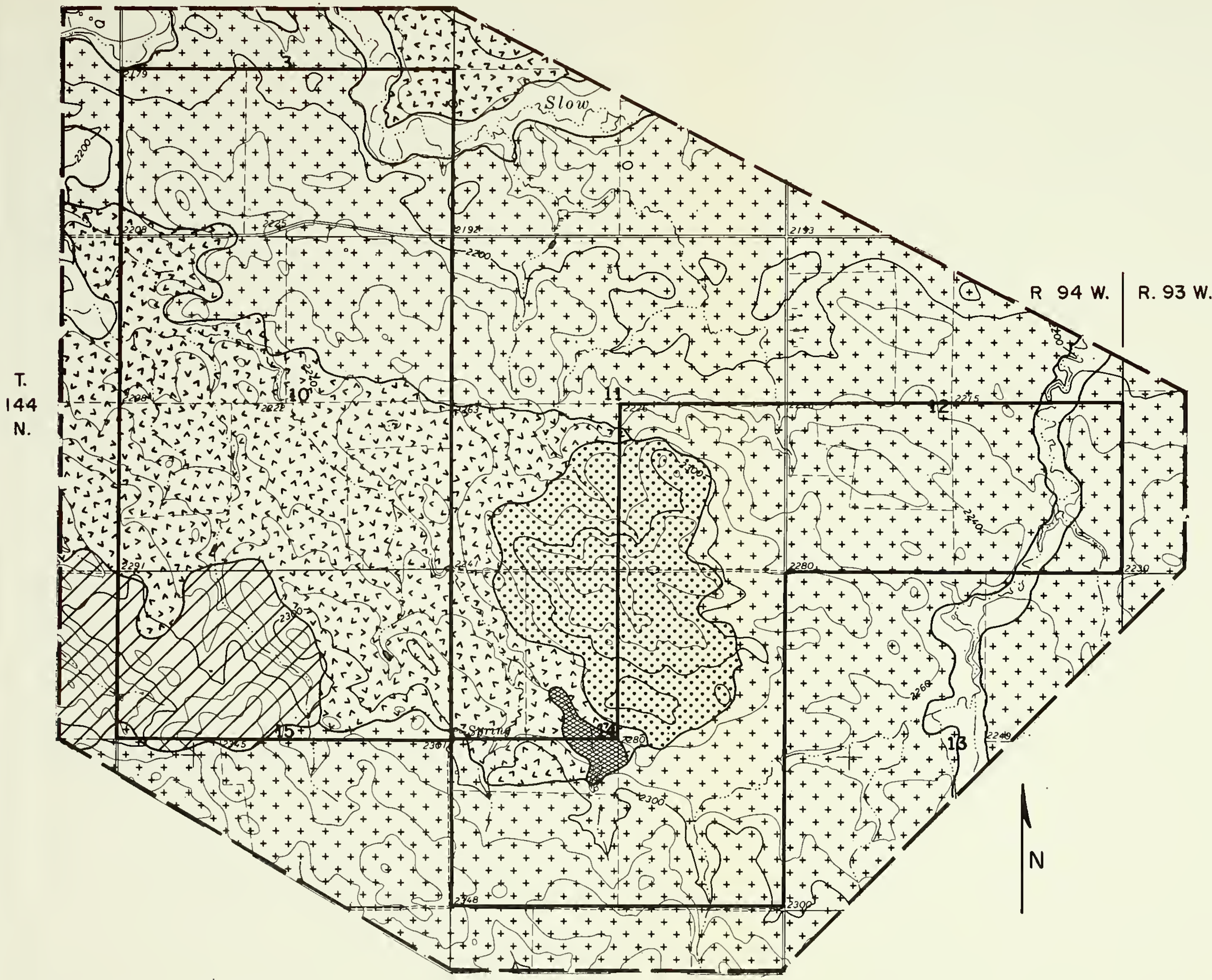
Interpretations of aerial photographs (1:22,000 scale) were used to extend the source-area sediment yield estimates to those areas that were not actually rated in the field. The aerial photographs were also used to classify all channels that were larger than about third order using Strahler's (1952) system of ordering. The slope data shown on Plate 25 were obtained from 1:24,000 USGS topographic quadrangles. The percentage of bare soil was measured by the first-contact-point method within selected vegetation types on the site, and estimates were made for the remaining types with the aid of the aerial photographs. Percent bare soil will vary seasonally particularly on the cropland. Vegetative cover on the rangeland is generally excellent, ranging from 90 to 100 percent in September 1975.

Results and Discussion

Source-area sediment yields for the study area as shown on Plate 25 are low to moderate, largely a result of the gently rolling nature of the terrain and the excellence of the vegetative cover. Values range from none in the bottomlands to about .4 acre-foot per square mile per year in the area where cropland comprises more than 50 percent of the source-area type. The sediment yield from the cultivated land is greater than from the rangeland and hayland because the soil is tilled and because there is little vegetative cover on the soil part of the time. Data shown in the explanation of Plate 25 indicates little correlation between estimated annual source-area sediment yields, and average source-area slope. The probable reason for this is the general lack of variation of slopes among the source-area types and the excellent cover on even the steepest slopes.

Approximately 74 percent of the total channel length of the mapped area is healed or stable gully, 10 percent is untrenched channel, and 1 percent is aggrading channel with only 15 percent raw gully based on the data shown in Table 24. These data indicate that channels are not important sediment contributors on the study area. There are headcuts present in some of the channels (Plate 26) but their advance appears to be very slow.

Basin sediment yields in the study area are low based on the estimates made for seven watersheds on and near the study area (Table 23 and Plate 26). This is the result of low source-area sediment yield and deposition along watercourses as discussed previously. The computed



EXPLANATION

	Annual source-area sediment yield (acre-ft/mi^2)	Topography	Slope Range (in percent)	Slope Mean (in percent)
[blank box]	0	Bottomland	0-3	1
[crosshatched box]	0	Alluvial flat	0	0
[hachured box]	0-.1	Hillslope	3-16	8
[dotted box]	.1-.2	Hill and valley	6-11	8
[v-pattern box]	.2-.3	Rolling upland	1-7	4
[plus-pattern box]	.3-.4	Rolling upland*	2-13	6

* More than 50 percent cultivated

——— EMRIA study area boundary

— — Boundary of mapped area

Base from U.S. Geological Survey
Dunn Center East, North Dakota
7½-minute quadrangle

1000 0 1000 2000 FEET

ANNUAL SOURCE-AREA SEDIMENT YIELDS FOR THE
HORSE NOSE BUTTE STUDY AREA--NORTH DAKOTA, 1975

Base from U.S. Geological Survey
Dunn Center East, North Dakota
7½-minute quadrangle

EXPLANATION

Basin	Drainage area (mi^2)	Estimated basin sediment yield range (acre-ft/mi^2)
A	.47	.10-.14
B	.21	.18-.26
C	.23	.15-.21
D	1.10	.14-.20
E	.21	.07-.10
F	.94	.12-.16
G	21.46	.1 -.2

— · — Drainage divides
—— EMRIA study site boundary
— — — Boundary of mapped area
● A Locations of the outlets of drainage basins for which sediment yield estimates were made.

CHANNEL CONDITIONS

	Symbol	Density (mi/mi^2)
Raw gully	———	0.57
Healed gully	—x—x—	2.77
Untrenched	— — — —	0.38
Aggrading	···········	0.05
Dam	▲	
Fan	(fan symbol)	
Headcut	■	

CHANNEL CONDITIONS AND DRAINAGE BASINS FOR WHICH SEDIMENT YIELD ESTIMATES WERE MADE ON THE HORSE NOSE BUTTE STUDY AREA--NORTH DAKOTA, 1975

Table 23.--Estimated basin sediment yields and associated basin characteristics

Basin[1/]	Drainage area (mi^2)	Percent of channel length in raw gully	Sediment Conveyance Factor (SCF)	Weighted source-area sediment yield (acre-ft/mi^2/yr	Estimated basin sediment yield (acre-ft/mi^2/yr
A	.47	19	.7	.14-.20	.1-.14
B	.21	20	.77	.24-.34	.18-.26
C	.23	6	.57	.27-.37	.15-.21
D	1.10	26	.53	27-.37	.14-.20
E	.21	0	.30[2/]	.23-.33	.07-.1
F	.94	10	.42	.28-.38	.12-.16
G	21.5	(Unmodified PSIAC method applied to basin)			.1 -.2

[1/] Locations of the basins are shown on plate 26.

[2/] Reservoir near mouth of basin which greatly decreases sediment conveyance.

Table 24--Densities of the various channel conditions shown on plate 26 (units in miles per square mile)

Basin or area	Size (mi^2)	Raw gully	Healed or stable gully	Aggrading	Untrenched	Total drainage density
A	.47	1.22	3.68	---	1.43	6.34
B	.21	.69	2.75	---	----	3.43
C	.23	.37	4.99	---	.37	5.73
D	1.05	1.05	2.80	.17	.07	4.09
E	.21	----	3.20	---	.92	4.12
F	.94	.36	3.07	---	----	3.43
Remainder of mapped area	4.21	.46	2.42	.05	.41	3.33
Total mapped area	7.37	.57	2.77	.05	.38	3.77

sediment conveyance factors (SCF's) shown in Table 23 are less than one (1.0) which indicates the study area, as a whole, is in a depositional phase of morphological development. The morphological cycle consists of a period when deposition is dominant within a basin followed by a shorter period when erosion and transport of sediment from the basin are dominant. Due to a complex of variables such as excellent ground cover, soil conservation practices, low drainage densities, low sediment availability, and the current climatological regime, sediment is being trapped within the basins. Much of this entrapment is occurring in the aggrading, healed gully (vegetated beds) and untrenched reaches of channels as well as on the low, narrow terraces along Slow Creek. Sediment is also being deposited in the few stockponds of the area.

SOIL

Soil and Bedrock Material

Description of Principle Soil Bodies

The soils of the Horse Nose Butte Study area can be placed in three major categories based primarily on their parent material, mode of development, and land form. These are: (1) soils developed on and from residual material, (2) soils developed on alluvial/colluvial material, and (3) soils developed from glacial deposits. The residual soils have the greatest distribution and represent 63 percent of the area. They are quite variable in physical and chemical quality, surface relief and depth to the parent material. Alluvial/colluvial soils occupy about 19 percent of the area. Since no major streams influenced the erosion and deposition, the alluvial and colluvial soils have quite similar physical and chemical characteristics but are found in different topographic position. About 8 percent of the area soils formed on or from glacial material. The remaining 10 percent include intricately intermixed alluvial and residual soils and eolian influenced alluvial material.

Residual Soils

The residual soils formed on material weathered from intertonguing soft shale, siltstone, or sandstone of the Sentinel Butte Formation. This formation is composed of sediments deposited in a continental environment which included swamps. Locally these swamps produced thick lignite beds. Weathered exposures of the formation are generally pale olive or yellowish-gray.

Residual soils in this study area are quite variable. These soils form a complex pattern and range from very shallow to deep, but most sandy soils are moderately deep. All residual soils are underlain by consolidated formation. The surface relief consists of gently rolling hills with some steep slopes. Four types of residual soil typify the general conditions.

Sandy residual soils have formed on material weathered from softly consolidated calcareous sandstone. A dark grayish-brown sandy loam surface layer has developed. This layer permits the rapid entry of water and there is little erosion and runoff from areas in native grass. These soils have a neutral reaction and are nonsaline. The surface relief is characterized by plan and convex slopes ranging from 6 to 15 percent. The available water-holding capacity of this soil ranges from moderate for the surface layers to low for the subsoil and lower soil horizons. This soil type lacks cohesiveness and the wind and water hazard is moderate unless it has a good vegetative cover. The substrata is relatively sterile and low cation exchange capacity is common. Water movement into and through this material, when disturbed, will be high but moisture retention will be low.

The sandy residual soil from disturbed areas will have few limitations for use in mined land reclamation. However, the subsoil and substrata is not suitable for topdressing material and should be placed below a layer of good quality topdressing material in reconstructed profiles.

The master site selected to represent the soil mantle of all sandy soils in the study area is Site 3. This soil is an eolian sandy mantle over glacial till. It will also represent other sandy soil derived from residuum, alluvium, and colluvium. The description of this profile and the laboratory results are recorded on Table 27, Appendix E.

The silty residual soils developed from siltstone and silty shale occur on rolling hills with surface gradients ranging from 3 to 9 percent. The depth of the soil mantle is 36 to 42 inches. The master site data recorded on Tables 25, 28, and 29, Appendix E, represent this type of soil which amounts to about 30 percent of the study area.

The surface layers are friable silt loam and silty clay loam with high organic matter. They are 7 to 12 inches thick and are nonsaline and nonsodic. Water intake is moderate and internal water movement is good which reduces or prevents surface erosion except during severe thunderstorms. Available water retained for plant use by these layers is moderate to high.

The subsoil is firm silty clay loam or silty clay which rests on weathered shale. This material is slowly permeable. It is usually nonsaline and nonsodic and moisture retention is high.

The surface layers are well suited for topdressing reconstructed profiles on mined lands. The subsoil is suitable for use near the surface; but, the substratum, if used near the surface, must be selected with care. The best suitable substratum material available should be used in the reconstructed profile and the marginal and adverse material should be placed below 36 inches in reconstructed profiles.

The clayey residual soils and local clayey, colluvial soils developed from soft clay shales are currently problem soils when used for dryland production of small grain. They also produce a limited amount of range forage. Depressed growth of native grass in semislick spots is common. Between the spots of adverse soil, the surface soil is of good quality in virgin tracts. The plow zone of dry-farmed tracts is usually good quality material.

Water enters this soil readily, but downward movement is restricted or stopped by the claypan subsoil. This layer also restricts root penetration to cracks formed by alternate wetting and drying or frost action. This subsoil is extremely hard when dry, firm when moist and the available plant nutrients and moisture levels are low. The claypan subsoil is a dark grayish-brown silty clay loam about 5 inches thick. It is usually saline. The substratum beneath the claypan and other clayey residual soils is a strongly sodic silty clay loam or silty clay. Laboratory data for the master site representing this soil type and some minor soils are recorded on Table 30, Appendix E.

In most tracts, only the surface layers should be stripped and stockpiled for topdressing reshaped spoils. The subsoils should be placed below 36 inches. Borrow material for the subsoil of reconstructed profiles can be taken from nearby deep soils or good quality bedrock material.

These clayey residual soils occur on relatively flat areas in the uplands and have a few inches of friable loam or clay loam surface soil of good quality. Most tracts have adequate good material suitable for use at or near the surface for revegetation with native grasses and will most likely be reclaimed for range. However, some tracts of this soil can be reclaimed for dryland farming of small grains. To attain this objective, borrow material from nearby deep soils, modification by mixing with good quality material, or other suitable methods must be used.

Minor residual soils include the very shallow erosive sandy soils with wind-worked surface material. This surface layer should be used as subsoil and topdressed with good quality material. This would provide adequate plant media for native grasses. Soils developed on baked rock (clinker) have surface layers and subsoils that are suitable for use at or near the surface. The baked rock substratum has no agronomic value but may be used for bank stabilization along drainageways or for roads. Some deep saline soils are intermixed with clayey local alluvium. They are included with the minor residual soils. All soils in this group are unsuited for use at or near the surface without modification or selective stripping.

Alluvial/Colluvial

The alluvial/colluvial soils in the study area are the most valuable for revegetating surface-mined areas. They are well drained and often more than 10 feet deep and have good physical and chemical properties. Laboratory data recorded on Table 26, Appendix E, are representative of this soil type. It is one of the best sources of high quality material for reclaiming mined land. The surface relief of gently sloping footslopes, fans and terraces where these soils occur are well suited for stripping and stockpiling material for use in reclaiming mined areas. Four types of alluvial/colluvial soils based on the time of deposition, texture and profile development occur here. The well-developed silty alluvial/colluvial soils are characterized by a friable silt loam surface layer overlying a firm clay loam subsoil. The substratum is most often a silt loam but does include some clay loam. Water enters and moves through the surface material at a moderate rate but the permeability of the subsoil is moderately slow. The amount of available water retained for plant use averages 0.18 inches per inch. Shrink-swell potential of this material is moderate.

The entire soil profile is well suited chemically and physically for use on the surface. It is nonsodic, nonsaline and slightly acid to moderately basic. There is no indication of toxicity to plant growth.

Some sandy alluvial soils are on old terraces. They are characterized by sandy loam surface layers over stratified loamy sand and sandy loam subsoil and substratum. These soils are very friable. The substratum has single-grain structure. The available water-holding capacity is low and the soils are drouthy. Moisture retained for plant use ranges from 0.06 inches per inch for loamy sands to 0.14 inches per inch for the sandy loam surface. The substratum would be susceptible to severe wind and water erosion if used on the surface. Water enters and moves through this sandy material readily.

Salinity and sodicity are not problems in this soil. Soluble salts are less than 1 millimho and the soil reaction is about neutral.

Areas of recent alluvial/colluvial soils contain a large quantity of high quality material suitable for use as plant media at or near the surface. The areal distribution is about 11 percent of the study area. The profile depth of these soils often exceed 11 feet. All of this high quality material should be considered for topdressing reshaped spoils if the area is mined. These soils are characterized by their friability, their depth of significant organic matter levels and their good chemical quality.

Soils of this type are moderately permeable and retain about 0.18 inch of available water for plants per inch of soil. The shrink-swell potential is low. Low salinity and sodicity are common characteristics of this material. Their neutral reaction further increases their value for plant media.

Minor alluvial/colluvial soils are largely composed of eolian sandy material. The only serious limitation of these soils is susceptibility to wind erosion. Limited available water-holding capacity is a minor limitation. This material should be used for subsoil in reconstructed profiles and topdressed with good quality material.

Glacial Soils

Glacial soils developed on till occur sporadically through the study area. Other till influenced soils and soils occurring in association with till are quite variable. They represent a small acreage here.

The soil mantle is usually sandy in the undulating uplands but is quite fine textured in degressional tracts. The surface layers of these soils are suitable for topdressing reshaped spoils of mined land. However, the surface layers of the shallow sandy phase is best suited for subsoil placement.

Locally the till is covered by a thin alluvial mantle. Here, the till substratum is a dense heterogeneous material with a bulk density of about 1.6 grams per centimeter. Texture ranges from loam to clay loam and the shrink-swell potential is moderate. Moisture retention is usually good and permeability varies with the texture.

The surface layers are usually friable high quality material but the subsoils should be buried and topdressed in reconstructed profiles.

Land Suitability and Classification

One of the primary objectives of the Horse Nose Butte Study was to determine the suitability of the overburden (soils and bedrock) as a source of surfacing material for use in revegetating the area if it is surface mined. This was achieved by a land classification survey which evaluated the quantity and quality of the overburden and the ease of stripping and stockpiling suitable material for the reclamation of mined land. The soil depth and characteristics were of major concern, but the quantity and quality of material of both soil and bedrock were evaluated using the same field and laboratory procedures. Topographic factors such as slope and rock cover were the only factors which influenced stripping and stockpiling. The classification evaluated the upper 10 feet of the overburden, the surface features of the land and the quality of the bedrock over 10 feet below the surface to 10 feet below the coal.

Land classification specifications were developed specifically for the study area. Four land classes, 1, 2, 3, and 6, were designated. These correspond to the system used by the Bureau of Reclamation in their land classification surveys. Soil factors included in the specifications for quality considerations were: texture, salinity, sodicity, permeability, infiltration capacity, erodibility, and available water-holding capacity. Because the topography and drainage of the reclaimed area will probably differ from present conditions, drainage other than the permeability of the material was not a factor. Quantity consideration was primarily the depth of suitable material. Slope formation outcrops and surface boulders were the only items included which would affect ease of stripping and stockpiling. However, only glacial erratics are a factor on the study area. The specifications used are shown on Table 31. Very steep slopes and formation outcrops are usually minor inclusions in topographically suitable tracts.

In this study area, Class 1 lands provide the most desirable and the most plentiful source of suitable material for revegetation. A large supply of highly suitable material which can be stripped and stockpiled easily is available from these lands. Class 2 lands have adequate resurfacing material, but is limited in quantity, is less desirable in quality, or is difficult and expensive to handle. Class 3 lands are similar to 2 except the deficiencies are greater or there is a combination of deficiencies. The Class 3 lands are a marginal source of material but under good management and handling can meet the plant media need for revegetation. Class 6 lands do not have adequate suitable soil or suitable bedrock material to meet

Table 31
United States
Dept. of the Interior
Bureau of Reclamation
July 1976

LAND CLASSIFICATION SPECIFICATIONS - SURFACE MINE RECLAMATION
Suitability of Overburden for Revegetation of Surface-Mined Areas
BLM/BR Cooperative Program EMRIA
Horse Nose Butte Site

Overburden Characteristics	Symbols: Basic Subclass	Symbols: Inform. & Defic.	Class 1	Class 2	Class 3
SOILS AND/OR BEDROCK	s				
Textures			Sandy loams to clay loams.	Sandy loam to silty clay loams.	Loamy sand to clay.
Coarse		v		Sandy loams sufficiently coarse to slightly reduce moisture retention, productivity, and may increase erosiveneas.	Loamy sand in sufficient quantity to moderately reduce moisture retention, productivity, and may increase erosivenesa.
Fine		h		Silty clay loam and clay should be placed below 12 inches in a reconstructed profile.	Silty clay loam and clay ahould be placed below 6 inches in a reconstructed profile.
Depth		d	36" or more of overburden that ia suitable for plant media.	18" or more overburden that ia suitable for plant media.	10" or more overburden that is suitable for plant media.
Sodicity		a	SAR not to exceed 9.0 in fine textured soils, but may be 20.0 with loamy sand. May be higher if compensated with residual gypaum.		
Salinity (EC x 10^3)		s	36" with 4.0	36" with 8.0 but ahould have 18" of material <4.0	36" with 12 but should have 10" of material <4.0
Moisture Retention		q	1.5" per foot of soil	1.0" per foot of soil	0.75 per foot of soil
Permeability		p	Adequate to provide a well drained and aerated root zone and an infiltration rate adequate to prevent serious erosion.	Slightly restricted; movement of drainage water and aeration in the lower root zone will be reduced. Infiltration rate may be reduced and eroaion hazard increased slightly.	Reatricted in the lower root zone and internal drainage may limit choice of plant species. Restricted infiltration may create serious but controllable erosion hazard.
Erodibility			Subject to alight erosion	Susceptible to moderate erosion	Susceptible to severe erosion but can be controlled with proper management.
TOPOGRAPHY 1/	t				
Slope		g	Leaa than 12%	Less than 20%	Less than 35%
Maaaive and Lenticular		r	Not applicable.		
Glacial Eratics				30 yards per acre	60 yards per acre
Weatherability 2/			Will break down readily upon exposure to the weather.	May require short period to break down upon exposure.	May require extended period to break down upon expoaure.
DRAINAGE			Because of land alterations by surface mining, present drainage conditions other than permeability of the material, drainage is not a factor in the classification.		
Claaa 6			Areas delineated in this class generally lack suitable material for atripping and stockpiling for surface use. One or a combination of the following deficiencies may result in the use of this class: (1) insufficient surface soil and bedrock of suitable quality at or near the surface; (2) topography which prevents general stripping and atockpiling; (3) rocklands with large amounts of massive indurated sandstone; (4) toxic overburden (soil and bedrock), on or near the surface. Reclamation of these lands will require material from outside the delineated area, from deep geologic strata, or special treatment of available material.		

1/ Not applicable to bedrock material.
2/ Applicable only to bedrock material.

Table 32 - Description of Land Classes

Class Subclass	% of Area	Overburden Characteristics	Land Features	Management Requirements
1	39.6	Land in this class has an average minimum depth of 36 inches of good or high quality overburden that is suitable for plant media. Usually this material is dark colored soil that has formed on deep alluvial, colluvial, and residual material. Medium texture is most common. Soil aggregates of these medium textured soils have moderate to good stability and water enters the material readily. Internal permeability is moderate and adequate moisture is retained for plant growth. This rate of water movement provides adequate aeration of the plant root zone. Soil material in this class is high in organic matter, nonsaline and nonsodic and there is no indication of toxic material. Below 24 inches the material is moderately calcareous. These lands usually have surplus high quality overburden that is suitable for topdressing or subsoil placement. This material when borrowed will enhance productivity of other tracts.	The surface relief comprises nearly level to gently sloping terraces, fans, foot slopes, and undulating uplands. Most of this land produces small grains and native range. Topographic features will not hinder stripping and stockpiling. Selective stripping can be accomplished easily. Native mid and short grasses are the most common range species.	These soils will be slightly susceptible to wind and water erosion but management practices such as vegetative mulch, mechanical roughing, or contour planting should be adequate control. For maximum use of soil in this land class, the upper 6-24 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum.
2s	35.4	Land in this class has an average minimum depth of 18 inches of fair and good quality overburden that is suitable for plant media. Usually this material is largely medium and moderately coarse textured soil that has formed deep colluvial and alluvial deposits and moderately deep residual soils. Textures range from sandy loams to clay loams. Good quality geologic material may be considered as a part of the 18-inch requirement. Below 18 inches the overburden is usually calcareous. Soil limitations other than depth include: clay rich layers, reduced moisture retention, restricted permeability, and layers that are saline and sodic. Soil aggregates of these dark colored soils have fair to good stability and water enters the material at a moderate rate. The internal water movement is adequate to provide aeration of the primary plant root zone. Also, adequate moisture is retained for plant use. The material that is suitable for use at or near the surface is nonsaline and nonsodic and there is no indication of toxicity.	The surface relief comprises nearly level to rolling foot slopes, side slopes, swales, and undulating uplands. Topographic features will not hinder stripping and stockpiling desirable material; also, selective stripping can be accomplished easily. Native mid and short grasses are the most common range species. Small grains are the principal dry farmed crops.	Selection of suitable material for use at or near the surface will require a review of the field data. There is adequate topdressing material, but care must be exercised in selecting nonsaline permeable material for the subsoil and substratum. Selective stripping and stockpiling to isolate subsurface material followed by selective placement is necessary for the best use of available material in this land class. With proper selection and placement, reclamation should not be difficult and average management should assure successful permanent revegetation.

Table 32 - Description of Land Classes (Con't)

Class Subclass	% of Area	Overburden Characteristics	Land Features	Management Requirements
2t	0.2	Land in this class has an average minimum depth of 36 inches of good and high quality overburden that is suitable for plant media. Usually this material is dark colored soil that has formed on deep alluvial, colluvial, and residual material. Medium texture is most common. Soil aggregates of these medium textured soils have moderate to good stability and water enters the material readily. Internal permeability is moderate and adequate moisture is retained for plant growth. This rate of water movement provides adequate aeration of the plant root zone. Soil material in this class is high in organic matter, nonsaline and nonsodic and there is no indication of toxic material. Below 24 inches the material is moderately calcareous. These lands usually have surplus high quality overburden that is suitable for topdressing or subsoil placement. This material when borrowed will enhance productivity of other tracts.	The surface relief comprises moderately steep side slopes, and selective stripping will be difficult.	These soils will be slightly susceptible to wind and water erosion but management practices such as vegetative mulch, mechanical roughing, or contour planting should be adequate control. For maximum use of soil in this land class, the upper 6-24 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum.
2st	0.6	The general description of overburden characteristics of Class 2s applies to this class. The most common soil limitations are depth of soil mantle and slowly permeable material in the subsoil and substratum. Also salinity and sodicity.	The surface relief comprises moderately steep rolling foot slopes and side slopes. Selective stripping will be difficult and some mixing of surface and subsoil material will occur.	A review of the field data to determine the effect of unavoidable mixing of surface and subsurface material is needed to determine best stripping depths. This will also be a guide for placement in a reconstructed profile. The last paragraph describing management of Class 2s applies to this class also.

Table 32 - Description of Land Classes (Con't)

Class Subclass	% of Area	Overburden Characteristics	Land Features	Management Requirements
3s	15.0	Land in this class has an average minimum depth of 10 inches of fair to good quality overburden that is suitable for plant media. Usually this material is largely medium to moderately fine textured soil that has formed on alluvial, colluvial, and residual deposits. The principal limiting soil factor is the limited quantity of nonsaline and nonsodic material for use at or near the surface. The subsoil and substratum often contain moderate to high amounts of sodium and large amounts of gypsum. They are saline and sodic. Laboratory tests indicate fair to poor permeability. Land in this class retains a large quantity of water for plant use. The infiltration rate and internal water movement are moderately slow. There is sufficient suitable material for revegetating for rangeland. Extensive borrowing of material would be required for profiles suitable for cultivation.	The surface relief comprises nearly level alluvial terraces and adjacent foot slopes. Topographic features will not hinder stripping and stockpiling desirable material and selective stripping can be accomplished easily. Native mid and short grasses are the most common range species. Some tracts produce mixed grass hay and a few poorly drained tracts grow only salt grass.	For best use of the soil in this class, the surface material must be stripped and stockpiled, and the subsoil and substratum should be placed with the spoil material. Pitting or gouging basins will retard erosion and promote leaching of soluble salts below the primary root zone. Mulches can also be used to reduce erosion. These measures can increase the effective leaching of soluble salts and increase production capability. Successful permanent revegetation can be accomplished, but above average planning and management will be required.
3st	1.0	Land in this class has an average minimum depth of 10 inches of fair to good quality overburden that is suitable for plant media. Usually this material consists of medium and moderately clayey residual soil and/or weathered shaley parent material. The major soil limitation is quantity of nonsaline and nonsodic material. There is adequate suitable material for revegetating for rangeland. Extensive borrowing of material would be required for profiles suitable for dryland. Locally the geologic material is permeable and the soluble salts can be leached. Some clay rich and sodium affected layers will most likely be included in the stockpiled material but this should be held to a minimum.	The surface relief of land in this class is characterized by gentle to moderate slopes below ridges. Moderate slopes will make selective stripping difficult. Native mid and short grasses are the dominant species. This land is used for range.	Selective stripping with emphasis on stripping small tracts of deep soil separately should be considered. In addition to a review of the data, a field check to locate these tracts is advisable. Similar surface treatment of reconstructed profiles as described in 3s should be followed.

Table 32 - Description of Land Classes (Con't)

Class Subclass	% of Area	Overburden Characteristics	Land Features	Management Requirements
6s	7.7 1/	Land in this class has less than 10 inches average depth of fair and good quality overburden that is suitable for plant media. These soils have formed on old alluvium and residuum. This material is clay rich below the surface layer and is often highly saline and/or sodium affected. One or a combination of the above factors make these soils unsuitable for plant media. Some small tracts with good quality soil occur in this class as inclusions.	The surface relief in this class comprises nearly level to very gently sloping old alluvial terraces and residual foot slopes and benches. Topographic features will not hinder selective stripping and stockpiling. Native mid and short grasses are the dominant range species.	A careful review of the data and field checking to locate the small inclusions of better soil is warranted. This combined with selective stripping can do much to reduce the amount of overburden that must be borrowed or modified. Temporary irrigation, pitting, and gouging basins to increase leaching may adequately modify some material. However, borrowing from nearby deep good quality soil areas will probably be the most economical method of permanent revegetation.
H 2/	0.5	Soils are a cross section of all classes, but generally are adequate in quality and depth for revegetation as range.		

1/ Includes a small acreage of 6st.
2/ Delineated and tabulated to show the amount of the area in homesteads that is occupied.

the revegetation needs in tracts delineated in this class. If these areas are disturbed by surface mining, it will be necessary to borrow suitable material for plant media or modify the available material to successfully revegetate Class 6 lands. These classes are described in more detail in Table 32.

Field mapping was done on a mylar overlay over aerial photographs with a scale 1:4,800. Topographic drawings at the scale of 1:24,000 with 20-foot contour intervals were used for reference when classifying the land. An abney hand level was used in the field to determine slope gradients.

The field studies were accomplished by selective placement of soil borings based on landform, parent material, changes in vegetation, appearance of the soil, and other observable land features. Twenty to 40 borings were made in each section of land. The maximum depth was about 11 feet with the average about 7 feet. Samples were collected from these borings and additional 5-foot borings were made to more accurately define land class boundaries. The surface layer subsoil, and substrata were exposed and evaluated for depth and physical and chemical characteristics to help determine potential of overburden material for use in mined land reclamation. Pertinent data were recorded for most profiles examined.

The soil profile was most often sampled by genetic horizons. However, composite samples were usually made of two near surface horizons under 10 inches thick or when characteristics were similar. Some areas are composed of 50-percent shallow claypan soils and 50 percent better quality soil that are intricately intermixed. The surface 12 inches were sampled as follows for testing in the laboratory and for greenhouse studies. Each soil type was sampled to a depth of 12 inches. Genetic horizons encountered to this depth were proportionately combined. Each soil sample was tested in the laboratory and greenhouse studies. Since the good soil and claypan soil cannot be selectively stripped, subsamples were taken from the above samples mixed 50/50 and tested for comparison. Results of this test on the composite (good/claypan soil) should indicate the type of material and its physical and chemical properties. This will be the type of material available for plant media from the surface 12 inches in these tracts.

Using the basic soil data collected and other observations in the field, a land suitability class was tentatively assigned each delineated tract while in the field.

Upon completion of the initial fieldwork, samples from tracts where more information was thought desirable were collected for additional study. Samples for these tests and greenhouse studies were taken from a pit dug to 4 feet and hand augered from 4 to 10 feet. A 25-pound sample was taken of each genetic horizon. Bulk density samples were obtained for some of the horizons in the upper 4 feet.

A soil laboratory was used extensively in the land classification survey. All soil samples were analyzed using screenable testing procedures. These tests include pH, settling volume, disturbed hydraulic conductivity, and soluble salts of a soil water suspension. Additional soil analyses were made as needed to confirm evaluations made using field data and the results of screenable tests. Complete analyses were made on samples from each genetic horizon of the master sites and the results are shown on Table 25 through 30, Appendix E. Exhibit 1, Appendix E, summarizes the screenable testing program. Tests and analyses listed in Exhibit 2, Appendix E, were performed as needed for proper evaluation of the overburden. Exhibit 3, Appendix E, is a glossary of terms that may occur in this report or similar reports prepared by other USBR Offices.

The land classification survey provides adequate data for developing the reclamation portion of the required mining plan. It does not, however, provide adequate detail for stripping and stockpiling operations immediately prior to surface mining. Although procedures similar to those used in the land classification can be used, additional field borings and observations supported by laboratory data may be required to more accurately determine the quantity, location, and quality of the available material suitable as a planting media to be stockpiled.

Results of Classification

The methods used to perform the survey have been described earlier in this chapter and Table 32 describes significant characteristics of the major land subclasses. Detailed land classification maps, Plates 27 through 32, Appendix E, record the location and distribution of the various classes. Brief profile notes and some screenable tests are also on these plates. The following tabulation lists the acres of land in each section by class and subclass:

Horse Nose Butte Study Area
Detail Land Classification

T. 144 N., R. 94 W.	1	2s	2t	2st	3s	3t	3st	6	H	Total
Section 3	139.8	120.0			30.3		7.2	22.7		320.0
Section 10	419.5	132.7	5.2	15.3	57.1		4.6	1.6	4.0	640.0
Section 11	49.9	74.3			14.0			21.8		160.0
Section 12	35.4	289.3			212.1			103.1		640.0
Section 14	279.5	127.4			17.8		9.3	38.7	7.3	480.0
Section 15	90.6	163.4			51.9		5.6	8.5		320.0
Total	1014.7	907.1	5.2	15.3	383.3		26.7	196.4	11.3	2560.0
Percent	39.6	35.4	0.2	0.6	15.0		1.0	7.7	0.5	100%

The results of the land classification are further summarized in Plates 33 and 34. These drawings graphically show the location, quality and quantity of the overburden (soil and bedrock) that is suitable for topdressing (see glossary) reshaped spoils. This information is slightly more general than the land classification maps but the data can be evaluated readily. Similar information about the substratum is presented in Plates 35 and 36.

Bedrock Suitability

A systematic evaluation was made of the core material described in Plates 10 through 21, Appendix A. Three drill holes were completed in tracts that will not be mined and were not analyzed and evaluated. The abundance of good material in tracts that are mineable will most likely preclude the use of material from outside the mining area. The bedrock material (overburden) was processed and analyzed in the laboratory and greenhouse using the same procedures as used on the soil samples. Results of the laboratory analyses are shown on Table 33, Appendix E. Selected samples were subjected to artificial weathering as described under GEOLOGY. These tests give some indications of how the materials will break down when exposed. Using the results from all tests and the detailed core descriptions on Plates 10 through 21, Appendix A., the suitability of the core material for use as plant media was evaluated. This information is recorded on Table 34, Appendix E, and on Plates 10 through 21, Appendix A. The applicable portion of the land classification standards provided criteria for the evaluation of this material which was then placed in one of three categories: suitable, limited suitability, or unsuitable.

Although similar criteria was used in the evaluation of land classes and suitability of core material, broader suitability classes were used on the bedrock (overburden) material. The "suitable class" is equivalent to Class 1 and the best of Class 2. The "limited suitability" class is equivalent to the lower half of Class 2 and Class 3 and "unsuited" is equivalent to Class 6. The type and quality of the bedrock material is quite diverse. The chemical and physical properties important to plant growth cannot be projected accurately for any great distance. Therefore, the quality determination of the core material applies only to the drilling site. However, as mining plans are developed, this will provide basic data on the probable location in the bedrock profile of both good and adverse material. The ease of separating and stockpiling suitable bedrock material occurring in moderate to large quantity was not a factor in the classification.

Thin bedded layers of potentially good material were noted but since separation would be nearly impossible, the dominant characteristics of each major geologic break were used in the suitability classification.

The weathered bedrock near the surface is quite diverse but most of the material is usable at or near the surface of reconstructed profiles. Major deficiencies are stability, permeability, and acidity. Stability of the material is most often influenced by the interaction of more than one factor. The following are the principal factors affecting stability: clay content, clay type such as montmorillonite, shrink-swell potential, sodium content, total soluble salts, and single grain structure. Permeability of the material is also usually influenced primarily by one of the following factors: clay content, sodium content, percentage of sand, presence of water stable aggregates, and absence of water stable aggregates. The acid material has some potential if mixed with better material. The deeper bedrock is usually quite sodic and should not be used on or near the surface; but, if placed at 30 to 36 inches below the surface in well drained tracts, it will restrict the downward movement of water and the utilization of natural precipitation will be high. Table 34, Appendix E, further describes the limitations of each bedrock zone sampled. The data collected and interpretations made from bedrock sampling should provide adequate information to determine the potential uses of bedrock material in developing mining and revegetation plans. It appears there is more than adequate supply of good and high quality soil material, and bedrock material will not be needed for use as plant media at or near the surface of mined land. Therefore, additional study of the bedrock material in relation to revegetation will be minimal.

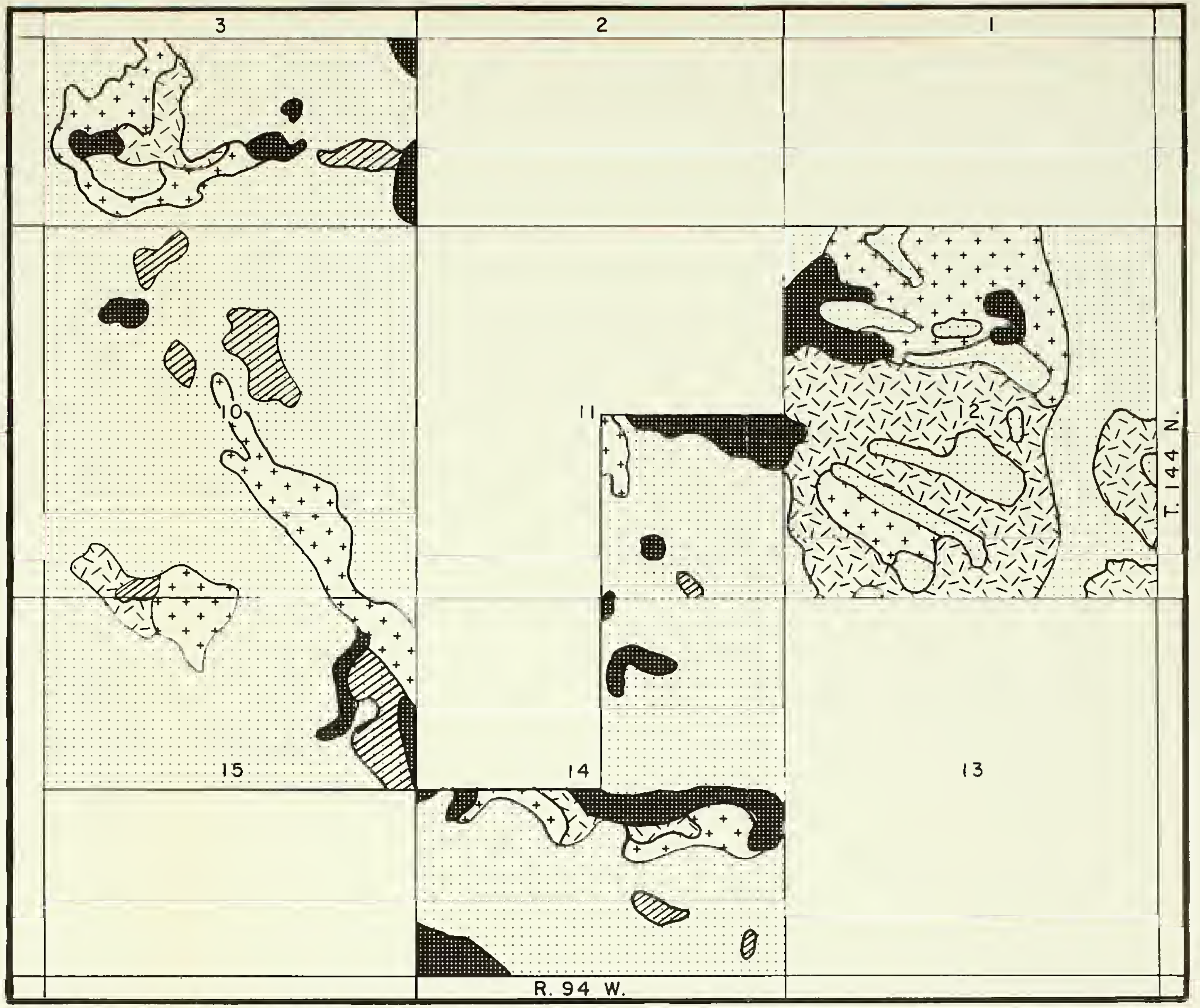
There is no indication of toxicity to plants or grazing animals that is related to soil or bedrock material in the study area. The lower bedrock material is highly sodic but most likely would not be toxic except to seedlings and only if used on the surface.

Soil Inventory

A soil inventory was made in the Horse Nose Butte Study Area to obtain soil and environmental data. Data from the inventory will be used to develop multiple resource management plans. Interpretation will be made by the BLM related to management of the lands before mining.

The soil inventory of the Horse Nose Butte Study Area was performed by the Soil Conservation Service in cooperation with the North Dakota Agricultural Experiment Station. The results of this survey are shown on Plate 37. This work was performed as part of an in-progress soil survey of Dunn County, North Dakota. The mapping identifies a total of 31 soil series and 1 land type. Mapping units in the area total 40. Each soil series is recognized as having characteristics differentiating it from other soils. Soil texture, color, thickness, parent material, physical and chemical properties, as well as climate and topography, influence and characterize each soil. Soils are generally evaluated to a 40-inch depth. Interpretative ratings for other uses and engineering properties are shown in Tables 35 and 36.

The 31 series consist of Entisols and Mollisols. The areal distribution of the Mollisols is much greater. In the 1938 USDA Soil Classification System, the majority of the soils were placed in the Chestnut great soil group.



EXPLANATION

- UNSUITABLE MATERIAL
- GOOD TO EXCELLENT TOPSOIL SOURCE
- SCATTERED STONES, REMOVAL NECESSARY
- FINE TEXTURED
- MODERATELY FINE TEXTURED

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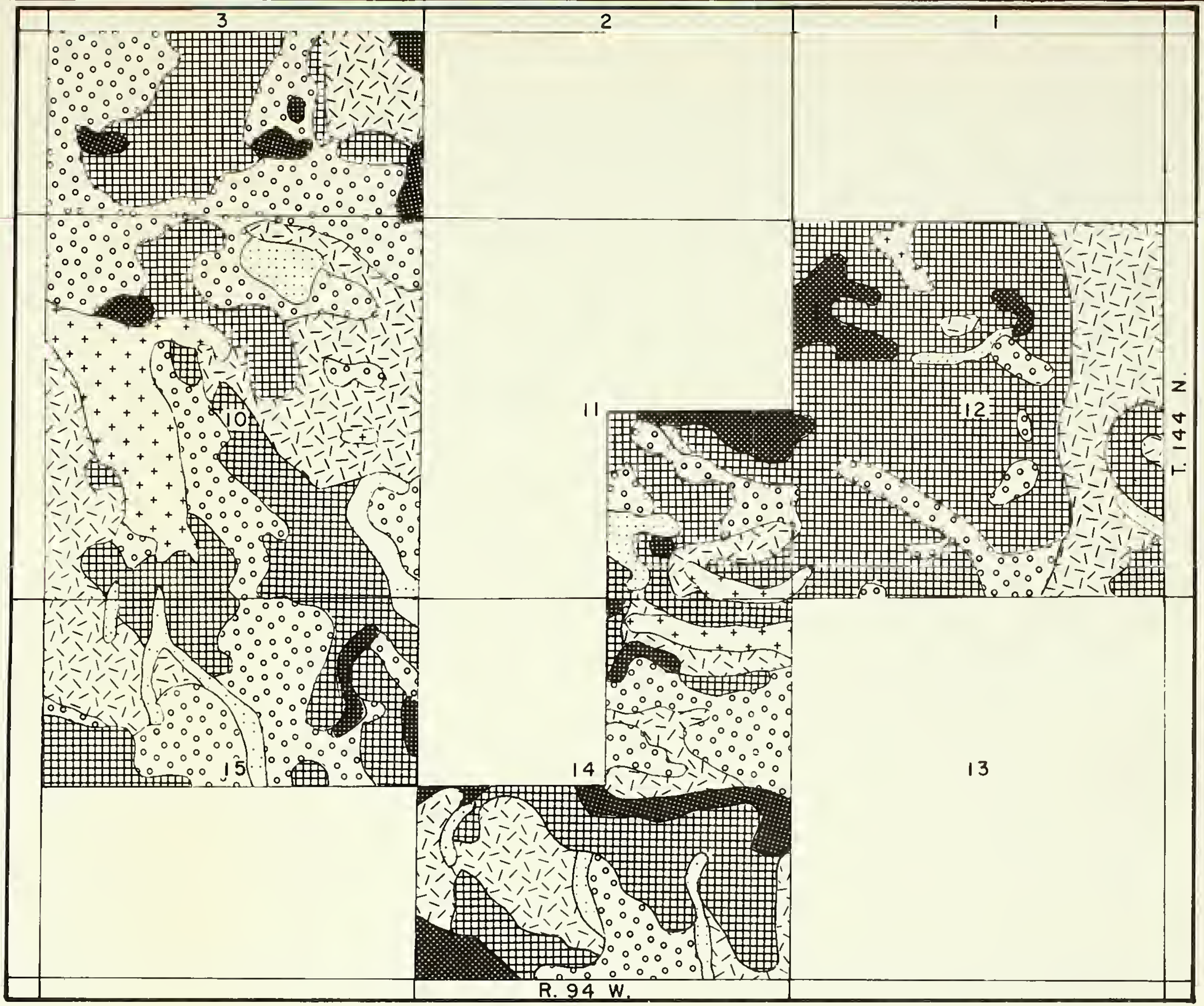
RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD
SOIL MATERIAL FOR TOP DRESSING
LOCATION — QUALITY

SOILS M. RONINGEN	SUBMITTED
DRAWN V. LINSSEN	RECOMMENDED
CHECKED	APPROVED
BILLINGS, MONT. APR. 1976	1305-600-96



EXPLANATION

- UNSUITABLE MATERIAL
- 6" — 12"
- 12" — 18"
- 18" — 24"
- 24" — 36"
- >36"

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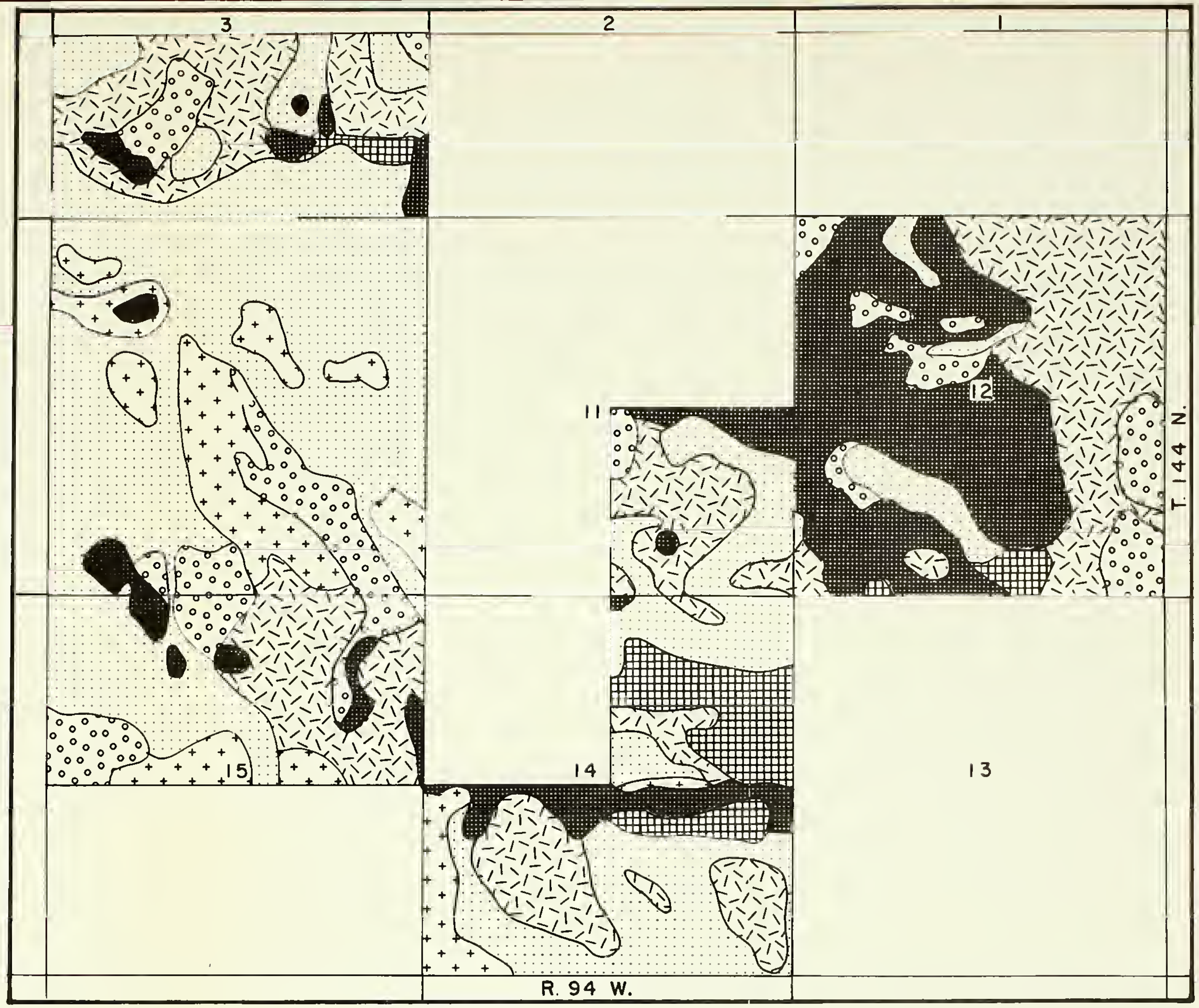
RESOURCE & POTENTIAL RECLAMATION EVALUATION

HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD
SOIL MATERIAL FOR TOP DRESSING
LOCATION AND THICKNESS

SOILS M. RONINGEN SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONT. APR. 1976 | 1305—600—97



EXPLANATION

- CLASS I QUALITY
- LIGHT TEXURED SOILS
- FINE TEXURED, SODIC OR SALINE
- SODIC AND SALINE
- SALINE
- CLASS 6

NOTE

Substrotum os used in this report is oll moteriol below the primory plont root zone consisting of lower soil C horizons ond weothered bedrock.

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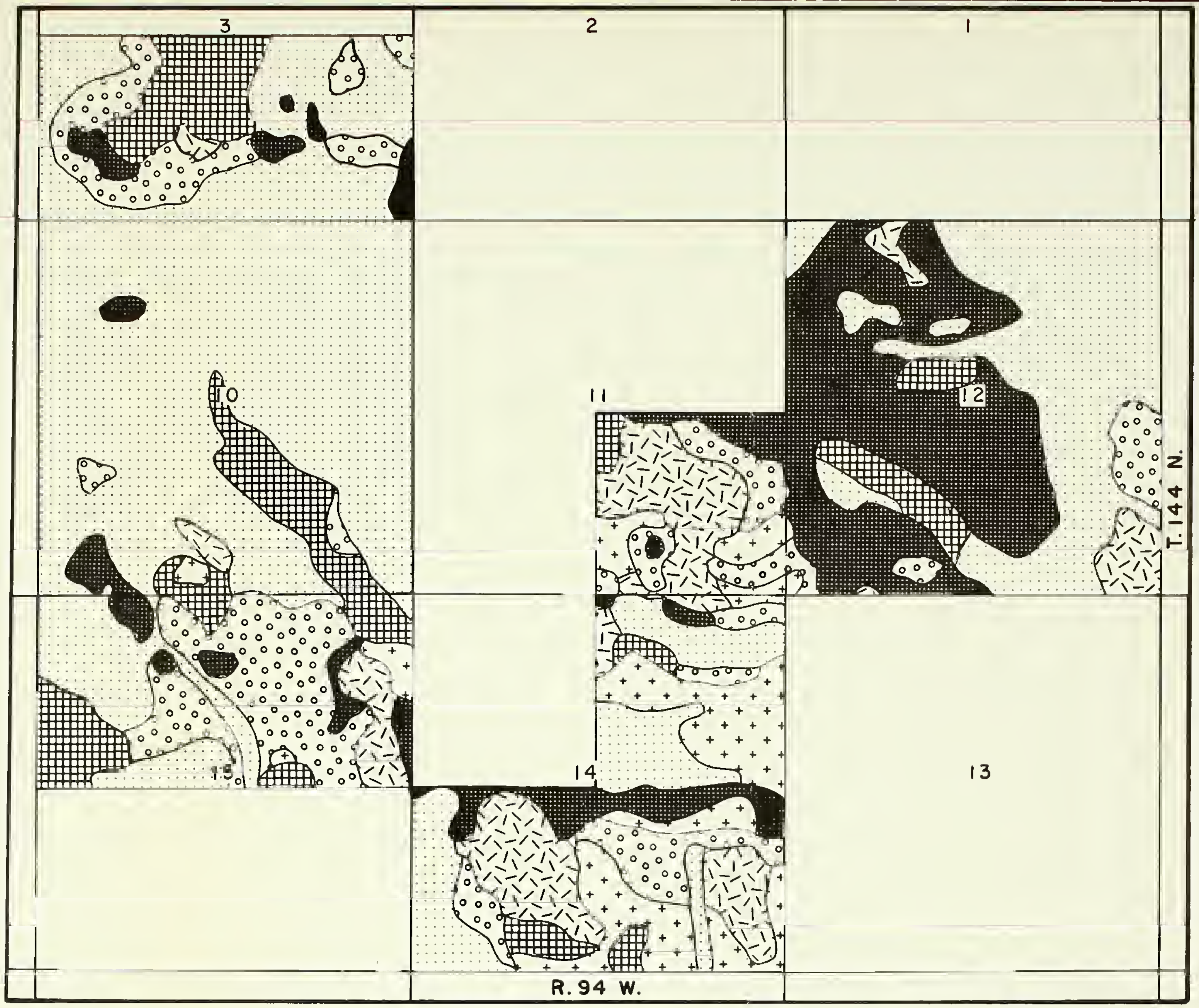
RESOURCE & POTENTIAL RECLAMATION EVALUATION

HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD
GENERALIZED SUBSTRATUM
QUALITY

SOILS M. RONINGEN SUBMITTED
DRAWN Y. LINSSEN RECOMMENDED
CHECKED APPROVED

BILLINGS, MONT. APR. 1976 | 1305-600-98



EXPLANATION

- 0
- 12"
- 12"–24"
- 24"–36"
- 36"–60"
- >60"

NOTE

Substratum as used in this report is all material below the primary plant root zone consisting of lower soil C horizons and weathered bedrock.

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RESOURCE & POTENTIAL RECLAMATION EVALUATION

HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

USABLE SUBSTRATUM
DEPTH IN INCHES

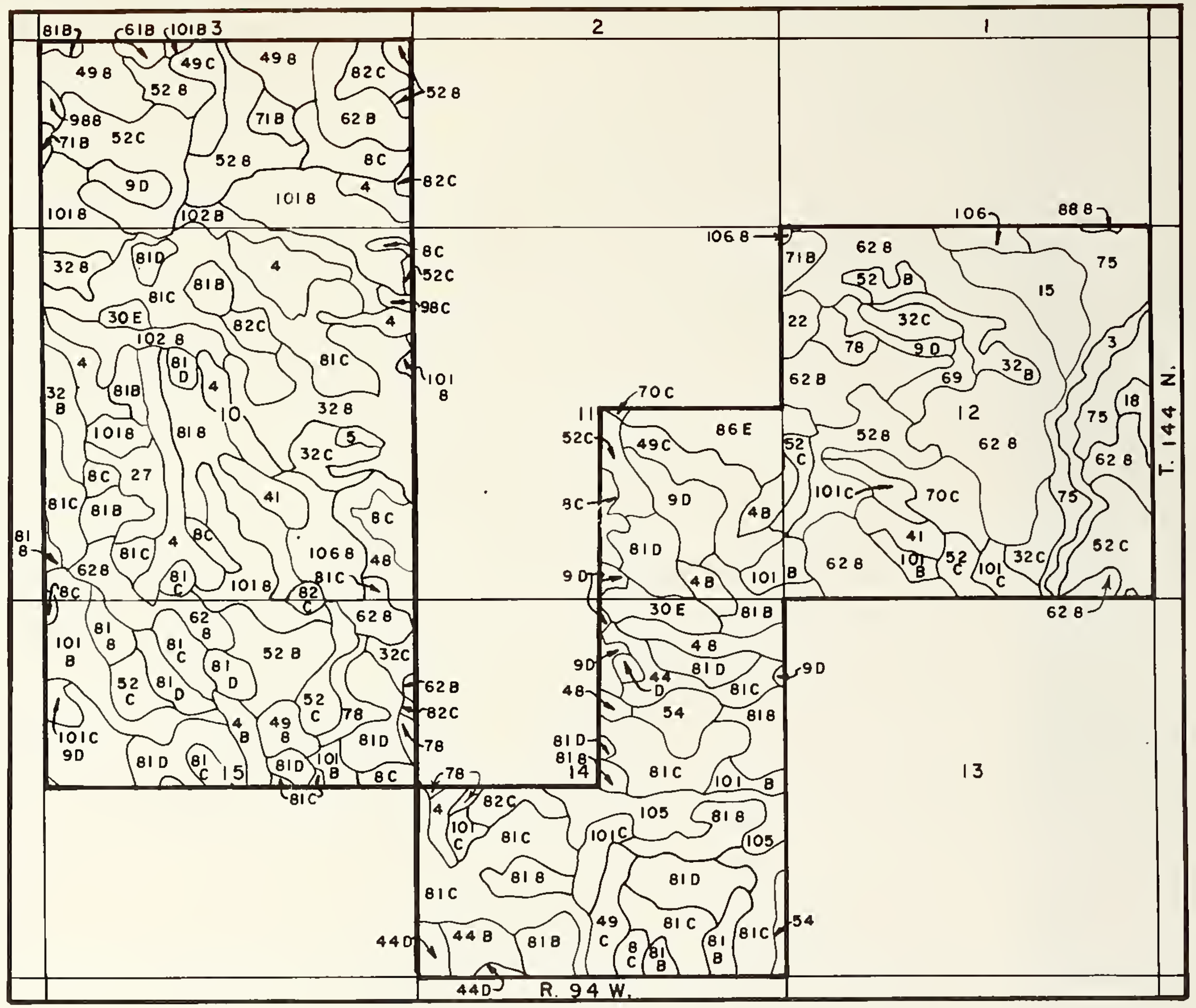
SOILS M. RONINGEN	SUBMITTED
DRAWN V. LINSSEN	RECOMMENDED
CHECKED	APPROVED
BILLINGS, MONT. APR. 1976	1305-600-99

IDENTIFICATION LEGEND

Dunn County, North Dakota
by Soil Conservation Service

August 1975

BLM No.	Mapping Symbol	Name	Included Symbols
9050	101B	Amor loam, 3 to 6 percent slopes	
9050	101C	Amor loam, 6 to 9 percent slopes	
9051	4	Arnegard loam, 1 to 3 percent slopes	
9051	4B	Arnegard loam, 3 to 6 percent slopes	
9052 9057	15	Belfield-Farland silt loams, 1 to 3 percent slopes	
9052 9076	18	Belfield-Grail silty clay loams, 1 to 6 percent slopes	
9053	86E	Brandenburg-Cabba complex, 6 to 25 percent slopes	
9054	9D	Cabba loam, 9 to 15 percent slopes	
9054	9E	Cabba loam, 15 to 45 percent slopes	
9054 9077	8C	Cabba-Chama silt loams, 3 to 9 percent slopes	
9077	98C	Chama silt loam, 6 to 9 percent slopes	
9055	30E	Cohagen fine sandy loam, 9 to 25 percent slopes	
9056	22	Colvin silt loam, saline	
9079	106B	Daglum silt loam, 1 to 6 percent slopes	14B,14C,106
9057	27	Farland silt loam, 1 to 3 percent slopes	
9058	32B	Flaxton-Williams complex, 1 to 6 percent slopes	
9059	105	Harriet complex, 0 to 3 percent slopes	
9060	41	Heil silty clay loam	
9061	44B	Lihen loamy fine sand, 3 to 6 percent slopes	44AZ
9062	49B	Morton silt loam, 3 to 6 percent slopes	
9062	49C	Morton silt loam, 6 to 9 percent slopes	
9062 9064	52B	Morton-Rhoades complex, 1 to 6 percent slopes	52
9062 9064	52C	Morton-Rhoades complex, 6 to 9 percent slopes	
9063	54B	Parshall fine sandy loam, 1 to 6 percent slopes	54
9080 9064	61B	Regent-Rhoades silty clay loams, 1 to 6 percent slopes	61
9064	62B	Rhoades complex, 1 to 9 percent slopes	62
9065	69	Savage-Rhoades silty clay loams, 1 to 3 percent slopes	
9066	70C	Searing loam, 6 to 9 percent slopes	
9067	71B	Sen silt loam, 3 to 6 percent slopes	
9067	71C	Sen silt loam, 6 to 9 percent slopes	
9068	102B	Shambo loam, 3 to 6 percent slopes	
9069 9070	75	Straw and Korchea silt loams, 1 to 3 percent slopes	
9069 9070	3	Staw and Korchea soils, channeled	
9069 9064	7	Straw-Rhoades complex, 0 to 3 percent slopes	
9071	78	Strongly saline land	
9072 9073	81B	Tally and Vebar fine sandy loams, 1 to 6 percent slopes	81,103
9078	44D	Telfer loamy fine sand, 6 to 15 percent slopes	
9074	5	Tonka silt loam	
9073	81C	Vebar fine sandy loam, 6 to 9 percent slopes	
9073	81D	Vebar fine sandy loam, 9 to 15 percent slopes	30D
9073	82C	Vebar extremely stony fine sandy loam, 3 to 15 percent slopes	
9075	88B	Williams loam, 3 to 6 percent slopes	



2000 0 2000 4000
SCALE OF FEET

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD
SOIL CONSERVATION SERVICE
SOIL SURVEY

SOILS ____ SUBMITTED ____
DRAWN V. LINSSEN RECOMMENDED ____
CHECKED ____ APPROVED ____
BILLINGS, MONT. APRIL 1976 1305-600-106

NOTE: DATA FROM IN PROGRESS SURVEY DUNN CO. N. DAK.

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DEPARTMENT OF THE INTERIOR
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HORSE NOSE BUTTE STUDY SITE
TABLE 35 INTERPRETIVE RATINGS FOR SOIL USES

Map Symbol (1)	Soil Name (2)	Suitability: Dryland Farming Wheat Yields High Management (3)	Suitability: Irrigation (4)	Suitability: Topsoil (5)	Suitability: Sand/Gravel (6)	Suitability: Road Fill (7)	Suitability: Other (8)	Degree of Limitation and Soil Features Affecting: Ponds: Location (9)	Ponds: Embankment (10)	Road Location (11)	Shallow Excavations (12)	Building Sites (13)
3	Straw-Korchea	26	good	good	unsuited	fair		moderate seepage	fair to poor	occasional flooding	severe flooding	occasional flooding
75	Straw-Korchea Channeled	--	--	good	unsuited	fair		moderate seepage	fair to seepage	occasional flooding	severe flooding	occasional flooding
4-4B	Arnegard Loam	29	good	good	unsuitable	fair		seep potential	semi-pervious	moderate	slight	moderate
8C	Cabba Chama SiL	18	unsuited	fair	unsuited	fair		slopes	moderate shrink-swell	moderate	moderate bedrock @ 20-40"	moderate
9D	Cabbs Loam	12	unsuited	limited amount	unsuited	fair		steep slopes	low shrink-swell	slight	moderate	moderate
9E	Cabba Loam	--	unsuited	limited amount	unsuited	fair		steep slopes	low shrink-swell	slight slopes	moderate	moderate
15	Belfield-Farland	23	unsuited	fair to 12"	unsuited	poor		favorable	moderate shrink-swell	severe	slight	moderate
18	Belfield Grail	23	unsuited	fair to 12"	unsuited	poor		favorable	moderate shrink swell	severe	slight	moderate
22	Colvin SiL Saline	--	unsuited	poor	unsuited	poor		suitable	fair piping hazard	high water table	severe	severe
27	Farland SiL	25	slow infiltration slow perm.	fair	unsuited	fair		moderate permeability	fair-good	moderate	slight	moderate
30E	Cohagen FSL	--	unsuited	poor	unsuitable	fair-poor		high seep potential	fair	severe	moderate severe	moderate severe
32B-32C	Flaxton-Williams Complex	21	mod. infiltration slow perm.	fair	unsuitable	good		rapid perm. 0-2', mod. slow 2'+	good stability	moderate	slight	moderate
41	Heil SiCL	--	unsuited	poor	unsuitable	fair		favorable	unstable	severe	severe	severe
44B,D	Lihen LFS	13	rapid infil. perm. low avail. water holding cap.	fair	unsuited	good		rapid perm.	severe	slight	severe sidewall stability	slight
49B,C	Morton Silt Loam	24	unsuited	fair	unsuited	fair		moderate	fair to good	moderate	moderate	moderata
52B,C	Morton-Rhoades Complex	19	unsuited	fair - poor	unsuited	fair to poor		moderate - favorable	fair to good	moderate	moderate	moderate to severe
54	Parshall FSL	20	mod. infil. rapid perm.	good	unsuitable	good		high seepage potential	fair stability semi-pervious	slight	slight	slight
61B	Regent-Rhoades SiCL	19	unsuitable	fair - poor	unsuitable	poor		favorable	high shrink swell	severe	severe	severe
62B	Rhoades Complex	--	unsuitable	poor	unsuitable	poor		favorable	high shrink swell	severe	severe	severe
69	Savage-Rhoades SiCL	18	unsuited	fair to poor	unsuitable	poor		favorable	high shrink swell	severe	moderate severe	severe
70C	Searing L	18	mod. infil. rapid perm. 28"+	good	unsuited	fair		mod. perm. 0-28" rapid perm 28"+	poor	slight	mod. porcelanite beds 20-40"	moderate
71B	Sen Silt Loam	22	unsuited	fair	unsuitable	fair		moderate permeability	fair to poor stability	moderate	moderate	moderate
78	Strongly Saline Lands	--	unsuited	poor	unsuitable	poor		suitable	fair piping hazard	severe	severe	severe
81B	Vebar FSL	15	unsuitable	fair	unsuitable	good		mod. rapid perm.	semi-pervious	slight	moderate	slight
81C	Vebar FSL	12	unsuitable	fair	unsuitable	good		mod. rapid perm.	semi-pervious	slight	moderate	slight
81D	Vebar FSL	--	unsuited	fair	unsuitable	good		mod. rapid perm.	semi-pervious	slight	moderate	slight
82C	Vebar FSL Stony Phase	--	unsuitable	fair - poor	poor	good		mod. rapid perm.	semi-pervious	slight	moderate severe	moderate
86E	Brandonburg Cabba Complex	--	unsuitable	thin	unsuitable	poor		excessive slope	poor compaction	slight severe slopes	severe	severe
98C	Chama Silt Loam	18	unsuitable	fair	unsuitable	fair		slopes	low-mod. shrink swell	moderate	moderate	moderate
101B,C	Amor Loam	21	unsuitable	fair	unsuitable	fair		mod. perm.	fair compaction	moderate	slight	moderate
102B	Shambo Loam	23	moderate to slow perm.	good	unsuitable	fair		rapid perm. in substratum	fair compaction	moderate	slight	moderate
105	Harriet Complex	--	unsuited	poor	unsuitable	poor		high water table	unstable	severe	severe	severe
106&106B	Daglum Silt Loam	14	unsuited	good to fair 8"	unsuitable	poor		favorable	high shrink swell	severe	severe	severe

Note: These data are from Soil Conservation Service soil surveys.

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HORSE NOSE BUTTE STUDY AREA

TABLE 36 ENGINEERING PROPERTIES OF SOILS
MEASUREMENTS AND INTERPRETATIONS

Map Symbol (1)	Soil Name (2)	Depth from Surface of Typical Profile (inches) (3)	Depth to: Bedrock (4)	Depth to: Seasonal High Water Table (inches) (5)	Hydro-logic Soil Group (6)	Shrink-Swell Potential (7)	Corrosivity: Uncoated Steel (8)	Corrosivity: Concrete (9)	Classification: USDA Ext. (10)	Classification: Unified (11)	Classification: AASHO (12)	Coarse Fraction (percent) (13)
3-75	Straw-Korchea	0-60	>6'	>60	B	low-moderate	Moderate	low	Loam Silt Loam	ML-CL	A-4 A-6	--
4-4B	Arnegard Loam	0-40 40-60	>5' -	>60 -	B -	low low to moderate	Moderate moderate	low low	Loam Clay Loam	ML ML-CL	A-4 A-4 A-6	-- --
8C	Cabba SiL	0-14 14-60	<1-2/3 -	>120 -	C -	low to moderate	high high	low moderate	SiL Soft Loamy Shale	ML-CL -	A-4 A-6 -	-- --
9D		14-60	-	-	-	moderate	high	moderate	Soft L. Shale	-	-	--
9E		14-60	-	-	-	moderate	high	moderate	Soft L. Shale	-	-	--
15 & 18	Belfield	0-10 10-28 28-60	>3 1/3 - -	>120 - -	C - -	low to med. high moderate	moderate high high	low moderate high	SiL SiC SiCL	ML-CL CH CL	A-6 A-7 A-7 A-7	-- -- --
22	Colvin SiL Saline	0-60	>5'	>12-48	D	moderate	high	moderate	SiL SiCL	CL	A-6 A-7	--
27	Farland SiL	0-60	>5'	>120	B	moderate	moderate	low	SiL SiCL	CL	A-6 A-7	--
30E	Cohagen FSL	0-17 17-60	<1-2/3 -	>120 -	B -	low low	moderate moderate	low low	FSL Soft Sand-stone	SM -	A-2 A-4 - -	5 --
32B & 32C	Flaxton	0-28 28-60	>5 -	>120 -	B	low moderate	moderate moderate	low moderate	FSL CL	ML-SM CL	A-2 A-4 A-6	-- 5
41	Heil SiCL	0-60	>5	0-84	D	high	high	high	SiC SiCL	CL-CH	A-7	--
44BD	Lihen LFS	0-60	>5	>120	A	low	moderate	low	LFS	SM	A-2	--
49BC	Morton	0-33	1-2/3- 3-1/3'	>120	C	low to mod.	moderate	low	SiL	ML-CL	A-4 A-6	--
	SiL	33-60		>120	C	low to mod.	moderate	low	Soft Siltstone	ML-CL	A-4 A-6	--
52BC	Morton Rhoades	See Morton and Rhoades										
54	Parshall FSL	0-30 30-55	5	>60	B	low low	moderate moderate	low low	FSL LFS	SM SM	A-4 A-2 A-2 A-4	-- --
61B	Regent Portion	0-38 38-60	2-1/2- 3-1/3	>120	C	moderate high	high high	moderate moderate	SiCL SiC Soft Clayey Sh	CL --	A-6 A-7 --	-- --
62B	Rhoades	0-15 15-60	2½	>120	D	high mod.very high	moderate high	moderate high	SiC-SiCL Cl SiCL	CL-CH CL-CH	A-7 A-6 A-7	-- --
69	Savage Portion	0-60	5	>120	D	moderate	moderate	moderate	SiCL SiC	CL	A-6 A-7	--
70C	Searing Loam	0-28 28-60	1-2/3- 3-1/3	>120	B	low to moderate	moderate	low	Loam Porce-lanite	ML-CL	A-4 A-6	5
71B	Sen Silt Loam	0-34 34-60	2-3½	>120	C	moderate moderate	moderate moderate	low low	Loam Soft L. Shale	ML --	A-4 --	-- --
78	Strongly Saline Lands	0-60	>5	0-60	D	no values applied						
81B,C,D 82C	Vebar FSL	0-34 34-60	1-2/3- 3-2/3	>96	B B	low low	moderate moderate	low moderate	FSL Soft fine Grained Sandstone	SM --	A-2 A-4 --	
86E	Brandon-burg Portion	0-4 4-10 10-60	≤1½	>120	B	low low low	moderate moderate high	low low low	Gr. L Channery Porcel-anite beds	ML SM GM SM	A-2 A-4 A-1 A-2	5-15 25-30
98C	Chama SiL	0-34 34-60	1-2/3- 3-1/3	>96	C	moderate low to moderate	moderate high	low moderate	SiCL Soft Silt-stone	CL-CH	A-7	
101B,C	Amor Loam	0-13 13-31 31-60	1-2/3- 3-1/3	>72	C	low-med low-med low-med	moderate moderate moderate	low low moderate	Loam Loam Soft Grained Sandstone	ML CL ML CL	A-4 A-6 A-4 A-6	
102B	Shambo Loam	0-46 46-60	>3½	>72	B	low to moderate low	moderate moderate	low low	Loam Gr SL	ML CL SM GM	A-4 A-6 A-1 A-2	30
105	Harriet Complex	0-40 40-46 46-60	>5	0-72	D	Mod.to high Mod.to high Mod.to high	high high high	high high high	SiCL L SiC	CL CH ML CL CH	A-6 A-7 A-4 A-6 A-7	
106 & 106B	Daglum Silt Loam	0-8 8-20 20-26	>3-1/3	>120	C	moderate high high	high high high	low high high	SiL C SiC-CL	CL CH CL	A-6 A-7 A-6 A-7	

Note: These data are from Soil Conservation Service soil surveys.

Description of Soils

This section names the soil series and describes the mapping unit in the Horse Nose Butte Study Area. The acreage and percent of the area are also given. The descriptions given here list briefly the general soil characteristics as they apply to present management and to provide general information on their suitability for use in reclaiming mined land. The results of this inventory are shown on Plate 37.

The toxinomic soil units are described together as to general characteristics, landform position, and technical evaluation related to management.

Map Symbol	Series	Phase	Acres	Percent
101B, 101C	Amor	Loam	247	9.7

The Amor soils are moderately deep residual soils that developed from soft sandstone, siltstone and loamy shales of the Sentinel Butte Formation. These soils are generally on uplands with 3 to 9 percent slopes.

The surface soil is generally a dark, grayish-brown friable loam 8 inches thick over a brown-to-brownish-gray hard, friable loam subsoil 10 inches thick. The substratum is a calcareous light-gray loam containing a calcium carbonate equivalent of over 10 percent. Depth to weathered sandstone or siltstone typically is 30 to 40 inches.

These soils are presently used for small grains, hay and pasture.

For complete chemical and physical properties, see Master Site No. 5, Table 29, Appendix E.

Map Symbol	Series	Phase	Acres	Percent
4, 4B	Arnegard	Loam	172	6,8

Here the Arnegard series are alluvial soils derived mainly from calcareous sedimentary rock and glacial till. These soils occur in the swales and depressions in a concave position with slopes ranging from 0 to 6 percent.

The surface soil is typically a dark, grayish-brown, very friable loam about 8 to 18 inches thick. The subsoil is a grayish-brown friable loam, 12 to 36 inches thick. The substratum is a calcareous fine sandy loam to friable clay loam. Bedrock or glacial till may occur below 40 inches, but more often depth to these materials is greater than 120 inches.

The Arnegard series is the most valuable soil in the area for reclamation use. Efforts should be made to stockpile this material from depths of 120 inches or more,

These soils are presently used for small grain, hay, and pasture.

For example of chemical and physical properties, see Master Site No. 2, Table 26, Appendix E.

Map Symbol	Series	Phase	Acres	Percent
15, 18	Belfield in Complex with Farland and Grail	Silt Loam/ Silty clay Loam	51	1.9

The Belfield soils are formed in alkaline residuum or alluvium. They occur on a nearly level terrace in complex with the better quality Farland and Grail soils and with similar but shallower Rhoades soils. Slopes are less than 3 percent.

The surface soil is typically a grayish-brown silt loam to silty clay loam 7 to 12 inches thick. The subsoil is a very hard grayish-to-olive-brown, strong, prismatic, silty, clay loam to silty clay, from 12 to 20 inches thick. The substratum is a calcareous, often sodic and saline light, brownish-gray to light olive-brown clay loam. The Farland and Grail soils that are mapped in complex with the Belfield lack the claypan horizon and are generally nonsaline and nonsodic in the substratum.

These soils are presently used for small grain, hay, or pasture.

Map Symbol	Series	Acres	Percent
86E	Brandenburg	36	1.4

The Brandenburg soils occur on hilly-to-steep sedimentary plains with slopes of 10 to 25 percent. Large blocks of clinker 2 to 4 feet in diameter are abundant at the surface. This soil developed over clinker deposits.

The surface soil is a brown-to-pinkish-gray friable loam containing 10 to 20 percent coarse fragments and it ranges from 4 to 10 inches deep. The substratum is baked rock which is unsuitable for reclamation purposes.

Small tracts of this mapping unit may be stripped for topdressing material, if the cost of clinker removal and the steep slope gradient do not make it economically unfeasible.

These soils are presently in native grass and are unsuitable for cultivation.

Map Symbol	Series	Phase	Acres	Percent
9D	Cabba	Loam	73	2.9

The Cabba soils occur on moderately steep uplands with slopes ranging from 9 to 15 percent. These soils usually occur in the convex position and their distribution is not extensive in the study area. They are residual in origin.

The surface soil is a grayish-brown friable loam about 7 inches thick. Subsoil is usually absent and the substratum is generally a calcareous light-gray to brownish-gray silt loam to loam that is friable when moist and very hard when dry. Weathered silty shale or siltstone occur at 18 to 24 inches.

Map Symbol	Series	Phase	Acres	Percent
8C	Chama	Silt Loam	60	2.3

The Chama soils consist of moderately deep, well-drained, gently sloping soils on uplands. These soils formed in material weathered from shale, siltstone, and fine-grained sandstone. Cabba soils occur in complex with this soil and occupy the convex portion of slopes.

The surface soil is a friable, dark grayish-brown silt loam about 7 inches thick. The subsoil is a friable, grayish-brown silt loam to silty clay loam about 7 inches thick, the lower part may contain greater than 10 percent calcium carbonate equivalent. The underlying material is a calcareous light gray silt loam to silty clay loam. It is very hard when dry and friable when moist. This layer is generally about 20 inches thick and overlies soft silty shale.

These soils are presently used for small grain, hay, and pasture.

Map Symbol	Series	Phase	Acres	Percent
30E	Cohagen	Fine Sandy Loam	22	0.9

The Cohagen soils are shallow and occur on moderate-to-steep slopes. They are not extensive in the study area. The depth to sandstone is typically 18 inches but ranges from 4 to 20 inches.

The surface soil is generally a grayish-brown, fine, sandy loam 3 to 8 inches thick. An olive-brown, fine, sandy loam or indurated sandstone substratum is common.

Overburden (soil and bedrock) from the shallow portions of this mapping unit are unsuitable for reclamation use.

Present land use is native grasses.

Map Symbol	Series	Phase	Acres	Percent
22	Colvin	Silt Loam (saline)	10	0.4

Colvin soils occur on nearly level concave swales and depressions in association with glacial till deposits. These soils have a low permeability and are poorly drained. Surface runoff from the mapping unit is low. A water table is often near the surface. Salinity originates in water percolating through nearby glacial till or residual upland soils areas as well as from the original parent material.

The surface soil is dark-gray, friable silt loams to silty clay loams, overlying a calcic horizon. Substratum is gleyed.

Due to salinity, sodicity, and physical characteristics, the Colvin soils in the study area are not considered suitable for use as plant media in reclamation plans.

The present land use is native grasses and aquatic vegetation.

Map Symbol	Series	Phase	Acres	Percent
106B, 106	Daglum	Silt Loam	39	1.6

The Daglum soils occur on nearly level to gently sloping terraces and fans. These claypan soils developed in alluvium.

The surface soil is a grayish-brown loam about 8 inches thick. Below this subsoil is a dark, grayish-brown firm columnar silty clay about 14 inches thick. The substratum is an alkaline firm silty clay usually saline and sodic. This soil often occurs in complex with the Rhoades soils.

These soils are presently used for production of small grains, hay, or pasture.

Map Symbol	Series	Phase	Acres	Percent
27	Farland	Silt Loam	18	0.7

The Farland soils occur on nearly level to gently sloping terraces and alluvial valleys. Slopes gradients range from 0 to 3 percent. This alluvial soil is generally associated with adjacent soils developed in residium.

The surface soil is a dark, grayish-brown, friable silt loam 7 inches thick. It rests on a hard, friable, prismatic, silty clay loam subsoil which is 10 to 24 inches thick. The substratum is a calcareous loam to silty clay loam. Depth to weathered bedrock is greater than 40 inches.

These soils are generally cultivated land used for small grain production.

Map Symbol	Series	Phase	Acres	Percent
32B, 32C	Flaxton Williams	Loam	151	5.9

The Flaxton series consist of deep, nearly level to gently sloping, well-drained soils. These soils are found on sand mantled glacial till deposits. Usually the Flaxton soils are fine sandy loam to light loams and occur in complex with the fine loamy Williams soils. The Williams portion of the complex is nil in the study area.

The surface soil is a dark, grayish-brown, friable light loam 8 to 10 inches thick. The upper portion of the subsoil is a friable, light loam over a firm, grayish-brown clay loam 10 to 16 inches thick. Below this substratum is a calcareous, firm, clay loam with many pebbles and a few stones. This glacial till material is often underlain by weathered siltstone or sandstone at a depth of 4 to 10 feet.

These soils are presently utilized for small grain, hay, and pasture.

For complete chemical and physical properties, see Master Site No. 3, Table 27, Appendix E.

Map Symbol	Series	Acres	Percent
105	Harriet	34	1.3

The Harriet soils consist of deep, nearly level, poorly drained soils that formed in clayey alluvium. These claypan soils occur on low terraces and bottom lands.

The surface soil is a gray loam about 2 inches thick. The upper part of the subsoil is a dark-gray clay loam about 4 inches thick. The lower part is grayish-brown firm calcareous clay loam about 12 inches thick with an accumulation of salt. The substratum is also calcareous and contains some salt.

These soils are usually utilized for hay or pasture.

Map Symbol	Series	Phase	Acres	Percent
41	Heil Silty	Clay Loam	24	0.9

The Heil series consist of deep, nearly level, poorly drained soils that formed in fine textured alluvium in flat-bottom basins. These soils have a claypan in the upper part of the subsoil.

The surface soil is a gray silt to silty clay loam 1 to 3 inches thick. The underlying claypan is a dark-gray firm clay about 4 inches thick. Below this, the subsoil is a gray, very firm clay about 15 inches thick. The underlying material is a calcareous, light-brownish-gray, and very firm clay.

This soil is presently utilized for hay or pasture.

Map Symbol	Series	Phase	Acres	Percent
44B	Lihen	Loamy Fine Sand	14	0.5

These soils consist of deep well drained material formed in eolian and reworked sandy glacial deposits. They occur on near level to gentle slopes with gradients of 3 to 6 percent.

Typically, this soil is loamy, fine sand to a depth of about 20 inches. The upper 7 inches are dark gray and the next 7 inches are very dark, grayish brown. Profiles may vary due to wind reworking. At 34 inches typically the profile is olive-gray, fine sand.

The top 20 inches of this soil may be used as a source of topdressing material; but, it is inferior to soils in surrounding mapping units. Material from these soils are best suited for subsurface fill below 24 inches.

Soils in this mapping unit are presently used for grass.

Map Symbol	Series	Phase	Acres	Percent
49B, 49C	Morton	Silt Loam	152	7.1

These moderately deep, well-drained residual soils occur on rolling uplands with 3 to 9 percent slope. The Morton soils formed from soft siltstone and shale.

Typically, the surface soil is a dark, grayish-brown silt loam 4 to 7 inches thick. The subsoil is a dark, grayish-brown silt loam grading to an olive-gray, calcareous silty clay loam with depth. This layer is about 20 inches thick. The underlying material is a grayish-brown calcareous loam that rests on platy soft siltstone and shale which occur at 36 to 42 inches.

This soil is presently utilized for small grain, hay, and pasture.

See Master Site No. 1, Table 25, Appendix E, for complete physical and chemical data.

Map Symbol	Mapping Unit	Acres	Percent
52, 52C	Morton-Rhoades Complex	228	8.9

This mapping unit is a complex of the Morton and Rhoades soils. The areal distribution of the Morton is greater than the Rhoades. Reclamation of this unit physically is similar to the Morton unit; but, resultant reconstructed profile will be somewhat inferior to the Morton due to the claypan Rhoades soils in the complex.

Soils in this mapping unit are presently utilized for small grains, hay, and pasture.

Map Symbol	Series	Phase	Acres	Percent
54	Parshall	Fine Sandy Loam	19	0.7

The Parshall soils consist of deep, nearly level to sloping, well-drained soils. They are formed in deep sandy loam of lacustrine and glacial outwash origin.

The surface soil is a very dark, grayish-brown fine sandy loam about 18 inches thick. Below this, the subsoil is dark, grayish-brown, very friable, fine sandy loam about 7 inches thick. The underlying material is mainly dark, grayish-brown, fine sandy loam to loamy fine sand.

These soils are presently utilized for small grains, hay, and pasture.

Map Symbol	Series	Phase	Acres	Percent
61B	Regent (Regent-Rhoades Complex)	Silty Clay Loam	5	0.2

The Regent soils occur in complex with the Rhoades (see description of the Rhoades soils) soils in the study area.

Regent soils consist of moderately, deep, well-drained, nearly level to sloping residual series on uplands. They formed in soft shale. The surface soil is a dark, grayish-brown silty clay loam about 7 inches thick. The underlying subsoil is a firm silty clay about 30 inches thick.

Color of the subsoil ranges from grayish-brown to olive. The lower pale olive portion contains segregated carbonates. Soft weathered shale underlies the subsoil. The Regent soils lack the claypan of the Rhoades soils.

This soil is used for small grain, hay, or pasture.

Map Symbol	Series	Acres	Percent
62B	Rhoades Complex	288	11.3

The Rhoades soils consist of deep, nearly level to sloping, moderately well-drained soils that have a claypan. They formed in material weathered from soft shale or in local alluvium derived from shale.

Typically, the surface soil layer is 1 to 2 inches thick. The upper part of the subsoil is a claypan consisting of dark, grayish-brown, very firm silty clay loam which is about 5 inches thick. The lower part is an olive, calcareous silty clay about 8 inches thick that usually contains some salt. The underlying material is a calcareous and strongly sodic olive silty clay loam to a depth of about 40 inches. Between 40 and 60 inches, the material is a pale olive silty clay.

The Rhoades soil occurs in complex with the Daglum soils which are deeper to the claypan. The Daglum soils occupy 40 to 50 percent of the unit.

These soils usually are utilized for grassland.

See Master Site No. 6, Table 30, Appendix E, for complete physical and chemical analysis.

Map Symbol	Series	Phase	Acres	Percent
69	Savage	Silty Clay Loam	13	0.5

The Savage soils in this study area are mapped as a unit with the Rhoades soils. These deep well-drained soils occur on nearly level to gently sloping terraces with 1 to 3 percent grade. Savage soils formed in deep clayey sediments.

The surface layer is a dark, grayish-brown silt loam to silty clay loam. Below this, the firm silty clay to silty clay loam subsoil material is about 18 inches thick. It is dark, grayish-brown in the upper part and grades to olive gray in the lower part. A calcareous gray to pale olive silty clay underlies the subsurface material.

Savage soils are utilized for small grains, hay, and pasture.

Map Symbol	Series	Phase	Acres	Percent
70C	Searing	Loam	27	1.0

Searing soils occur on 6 to 9 percent upland slopes. These soils formed in place from weathered sedimentary material. Baked rock (clinker) above burned out coalbeds underlie these soils. They are well drained.

The surface soil is a friable, brown loam 4 to 8 inches in depth. A 6- to 10-inch layer of dark, reddish-gray to reddish-brown loam underlies the surface soil. The weathered substratum is a reddish-yellow, friable moderately alkaline loam with 5 to 20 percent baked rock chips. This layer is 6 to 10 inches thick. Below this is a channery loam grading to baked rock.

This soil is utilized for small grains, hay, or pasture.

Map Symbol	Series	Phase	Acres	Percent
71B	Sen	Silt Loam	19	0.7

The Sen soils consist of moderately deep, well-drained soils on gently sloping to steep uplands. Slopes range from 3 to 9 percent. These soils formed on materials weathered from calcareous siltstone and very fine sandstone.

The surface soil is a dark, grayish-brown silt loam about 6 inches thick which rests on a silt loam subsoil about 12 inches thick. The underlying material is a pale-brown silt loam 24 to 36 inches thick. Silty shale is below the soil profile.

This soil is utilized for small grains, hay, and pasture.

See Master Site No. 4, Table 28, Appendix E, for complete physical and chemical analysis.

Map Symbol	Series	Phase	Acres	Percent
102B	Shambo	Series	40	1.6

The Shambo soils occur on gently sloping terraces with gradients of 3 to 6 percent. These soils formed from calcareous loam alluvium derived mainly from soft sandstone and shale.

Surface soil of the Shambo series ranges from 7 to 16 inches thick. It is a friable, grayish-brown to dark, grayish-brown loam. The subsoil is a grayish-brown friable loam 10 to 24 inches thick. Below this is a calcareous loam substratum 12 to 36 inches thick. It may be stratified with layers of sand, sandy loam, or silty clay loam.

These soils are presently utilized for small grain, hay, or pasture.

Map Symbol	Series	Phase	Acres	Percent
3, 75	Straw	Silt Loam	91	3.6

These soils occur in complex and are formed in alluvium on low terraces and bottom lands. They are deep, well-drained soils. The Straw series is a Cumulic Haploboroll, the Korchea is a Mollic Ustifluvent.

Typically, the surface soil is a friable, dark, grayish-brown silt loam to light clay loam. Organic matter decreases irregularly with depth and buried horizons may be present. Substratum is a grayish-brown, fine, sandy loam to light clay loam.

This soil is used for small grains, hay, or pasture.

Map Symbol	Land Type	Acres	Percent
78	Strongly Saline Lands	24	0.9

This mapping unit has saline to strongly saline soils. They are poorly drained with nearly level surface relief or are located in the bottom of swales or depressions. The soil material consists of a moderately thick layer of loam to silty clay loam. A seasonal water table or a capillary rise of moisture may contribute to the salinity of the soils in this mapping unit.

Reclamation potential on this land type depends on local chemical and physical properties. Special placement in reconstructed profile will usually be required for best use of this material.

Map Symbol	Series	Phase	Acres	Percent
81B	Tally	Fine Sandy Loam	190	7.4

The Tally soils are mapped as a unit with the Vebar soils. The Tally soils consist of deep, well-drained soils that formed in eolian deposits and sandy alluvium. Tally soils occur on alluvial terraces, fans, and foot slopes with 1 to 6 percent slope gradient. Theyare similar to the Vebar soils but lack the paralithic contact at 20 to 40 inches.

The surface soil is a dark, grayish-brown, fine sandy loam 8 inches thick. It is very friable, nonsticky, and nonplastic. Subsurface soil is a brown, very friable, fine sandy loam. The substratum is a calcareous, nonsticky, and nonplastic loamy, fine sand to fine, sandy loam.

This soil is commonly used for small grain, hay, and pasture.

Map Symbol	Series	Phase	Acres	Percent
44D	Telfer	Loamy Fine Sand	12	0.5

Telfer soils are located on nearly level to undulating uplands. These soils formed on wind and/or water deposited sands. They are excessively drained.

Typically, the surface soil is a dark, grayish-brown loamy sand to loamy fine sand. Below this is a fine- to medium-grained sand. Structure throughout the profile is single grained. Soft bedrock may occur below 40 inches.

Materials from this profile are best suited for substratum fill below 18 inches due to their erodibility and low water-holding capacity.

This soil is presently in grassland.

Map Symbol	Series	Phase	Acres	Percent
9E	Tonka	Silt Loam		

The Tonka soils are poorly drained soils occurring in closed depressions in glacial till areas. These soils are of minor extent in the study area and are not mapped as a separable series.

The surface soil is a black silt loam 10 to 13 inches thick overlaying a thin, leached gray horizon. below this, a dark-gray, firm, silty clay loam subsoil about 10 to 20 inches thick. The substratum is a gleyed, gray silty clay loam.

This soil is presently in native wetland vegetation.

Map Symbol	Series	Phase	Acres	Percent
81C, 81D, 82C	Vebar	Fine Sandy Loam	460	18.1

Vebar soils are on nearly level to rolling uplands. Slopes are plane to convex ranging from 6 to 15 percent. The soils formed in residual material weathered from soft calcareous sandstone. They are well drained.

The surface soil is a dark, grayish-brown, fine, sandy loam 6 to 10 inches thick and the subsoil is a brown, friable, fine, sandy loam 10 to 20 inches thick. The substratum is a yellowish-brown, fine sandy loam grading to a soft massive calcareous sandstone at 30 to 40 inches depth. The stoney phase of the Vebar will have similar reclamation potential but with additional cost for stone removal or disposal.

This soil is used for small grains, hay, or pasture.

The following tabulation summarizes the areas of land of each mapping unit occurring by sections in the study area. See identification legend for names of mapping units.

Mapping Unit No.	Total Acres	Unit %	Sec. 3	Sec. 10	Sec. 11	Sec. 12	Sec. 14	Sec. 15
3	23	0.9				23		
4	107	4.3	9	91			7	
4B	65	2.5		17	14	2	19	13
5	4	0.2		4				
8C	60	2.3	19	23	6		6	6
9D	73	2.9	10		29	9	7	28
15	44	1.7				44		
18	7	0.2				7		
22	10	0.4				10		
27	18	0.7		18				
30E	22	0.9		5	2		15	
32B	103	4.0		90		13		
32C	48	1.9		16		25		7
41	24	0.9		12		12		
44B	14	0.5					14	
44D	12	0.5					12	
49B	66	2.6	44					12
49C	116	4.5	18		32	49	17	
52B	135	5.3	53			52		30
52C	93	3.6	49	3	14			27
54	19	0.7					19	
61B	5	0.2	5					
62B	288	11.3	30	10		219		29
69	13	0.5				13		
70C	27	1.0			1	26		
71B	19	0.7	10			9		
75	68	2.7				68		
78	24	0.9				9	1	14
81B	190	7.4	2	71	5	2	101	9
81C	292	11.5		119			153	20
81D	137	5.4		10	18		39	70
82C	31	1.2	8	10			11	2
86E	36	1.4			32	4		
88B	1					1		
98B	3	0.1	3					
98	3	0.1		3				
101B	150	5.9		78	7	11	7	47
101C	97	3.8	53			20	18	6
102B	40	1.6	7	33				
105	34	1.3					34	
106	11	0.4				11		
106B	28	1.1	27			1		
	2560	100%	320	640	160	640	480	320

GREENHOUSE

Introduction

In the past, surface mining for coal generally resulted in burying of the soil and then attempts were made to revegetate the spoil. The spoil left exposed was usually from the stratum directly overlying the coal seam and often was not a suitable plant growth medium.

It is visualized that in future surface mining operations, the soil will be conserved and replaced. However, in some areas the soil will be thin or less suitable as a plant growth medium than spoil generated from certain overburden strata. The objective of this greenhouse study was to evaluate the suitability of overburden as plant growth media.

Methods

Field Capacity

The initial task in the greenhouse study was to determine the field capacity of the overburden samples. The equipment used to determine field capacity was: plastic tubes 1-3/4 inches in diameter, plastic cups, and plastic sheets. Four hundred grams of each overburden sample was weighed and placed in the plastic cylinders which had been sealed at the bottom by a plastic sheet, and packed by tapping the side of the cylinder. Twenty milliliters of water was then added (5 percent of the overburden by weight) and the top was sealed with a plastic sheet. After 24 hours, the bottom plastic sheet was removed and the dry overburden fell into the plastic cup, leaving the moist overburden in the cylinder. The dry overburden was weighed and the field capacity (FC) calculated by the following equation:

$$FC = \frac{20 \text{ g } H_2O}{400 \text{ g} - \text{Weight of dry overburden}} \times 100$$

The field capacity percentage was the basis for the amount of water each pot received daily.

Fertilizer Treatments

Two thousand grams of each bedrock and soil sample were weighed into each of two pots. Each pot was fertilized with 100 ppm of nitrogen as reagent grade $Ca(NO_3)_2$ and 80 ppm phosphorus as reagent grade $Ca(H_2PO_4)_2 \cdot H_2O$. The reagents were added in solution as 10 and 50 ml aliquots respectively, then mixed into the soils and overburden. Where sufficient soil material was not available for a 2 kg sample weights, the aliquot sizes were adjusted to maintain a fertility level of 100 ppm N and 80 ppm P.

Seeding and Growth

Western wheatgrass (Agropyron smithii var. Arriba) was the test species. This species was chosen because it is one of the most abundant native grasses in the Western United States and will probably be used in many revegetation programs.

At the time of seeding, approximately 250 g of overburden was removed from each pot. Then water was added to each pot to bring them to field capacity. Forty seeds were placed in each pot and the previously removed dry overburden placed on the seeds. All pots were then covered with paper to retard evaporation and to allow the water to move to the surface by capillary rise. The pots were checked daily and upon germination, each pot was uncovered and the date recorded. The date when ten plants had emerged and the severity of salt crusting were also recorded. After germination, all pots were weighed daily and deionized water was added to bring the soil to field capacity. Maximum water use was approximately 25 percent of field capacity per day.

When the majority of the plants, in all pots, reached a height of 10 cm, the number of plants in each pot was recorded and each pot was thinned to 16 plants.

Two highly productive loam soils were included in the experiment as overall standards (A_1 horizon Platner series and A_1 horizon Kimm series). Greenhouse data on the standard soils are included at the end of Table 37, Appendix F.

Plants were harvested after 56 days following seeding.

Harvesting

The plants were clipped at a height of 2 cm above the soil surface to minimize contamination by soil splashed on the plants during watering. The harvested plants were then washed in 0.05 normal HCl and rinsed in distilled water so tissue analysis could be done on the plant samples. The plants were dried in a forced air oven at 70° C for 24 hours and then weighed to the nearest 0.01 gram.

Observations taken at the time of harvest included (1) the presence of shoot growth from rhizomes; (2) the degree of soil surface cracking; (3) the amount of salt crusting; and (4) the average plant height.

In comparing average plant height and plant dry weight, it can be seen that there is no direct correlation. These differences are believed to be partially due to variation in light response in different seasons.

Also, within experiments, a portion of the variation appears to be related to the amount of shoot growth originating from rhizomes, in that overburden samples with a low yield and tall average plant height generally had very little or no growth from rhizomes while those samples with a high plant yield and a lower average plant height generally had a relatively large amount of growth from rhizomes. Also, the clayier samples generally had the largest amount of growth from rhizomes.

Results

Large differences in Western wheatgrass growth are evident on various overburden samples (Photograph 7). Because there was a wide range on plant dry weights from the standard soils in the four greenhouse experiments, relative yields will be used in this discussion. Actual and relative yields are presented in Table 37, Appendix F. Relative yield was calculated as a percentage of yield of the Platner standard soil from the respective greenhouse experiments. For purposes of this discussion, relative yields less than 33 percent will be considered low, 33-67 percent medium, and above 67 percent high.

Samples of bedrock from the Horse Nose Butte Study Area generally had relative yields of medium to high with 16 percent yielding low, 53 percent medium, and 19 percent high (Figures 20 and 21 and Table 37, Appendix F). Many of the samples are fine-textured and highly sodic. These bedrock samples might be expected to produce very little vegetation in the field because they would be almost impermeable to water.

With minor exceptions, soil profile samples from the Horse Nose Butte area produced well, with the majority yielding high. Eight percent of the soil profile samples yielded low, 42 percent medium, and 50 percent high (Figure 22, Table 37, Appendix F). Also, with few exceptions, the soil profile samples show favorable chemical and physical characteristics as plant growth media.

Discussion

Large differences in yield were noted among bedrock and soil samples. Overburden samples which had relative yields less than 33 percent would definitely not be suitable as plant growth media. The samples with relative yields larger than 33 percent include some strata which would make a favorable plant growth media, but also include some strata which would make unsuitable plant growth media under field conditions.

In the greenhouse study, overburden samples with the higher field capacities generally yielded the most. In the field, under arid and semiarid conditions, these fine-textured materials would be the more droughty soils because of greater surface runoff and evaporation. Thus, growth differences reported in this greenhouse study will give only an indication of the overburden suitability as a plant growth media. When extrapolating greenhouse results to field conditions, the physical and chemical characteristics of the overburden must be analyzed along with the greenhouse yield data to make interpretations on the suitability of the strata as a plant growth media.

Greenhouse Yields and Observations

The degree of surface cracking of the overburden was given a numerical designation as follows:

0 - none
1 - very slight
2 - slight
3 - moderate
4 - extreme

The degree of salt crusting was also observed and recorded as follows:

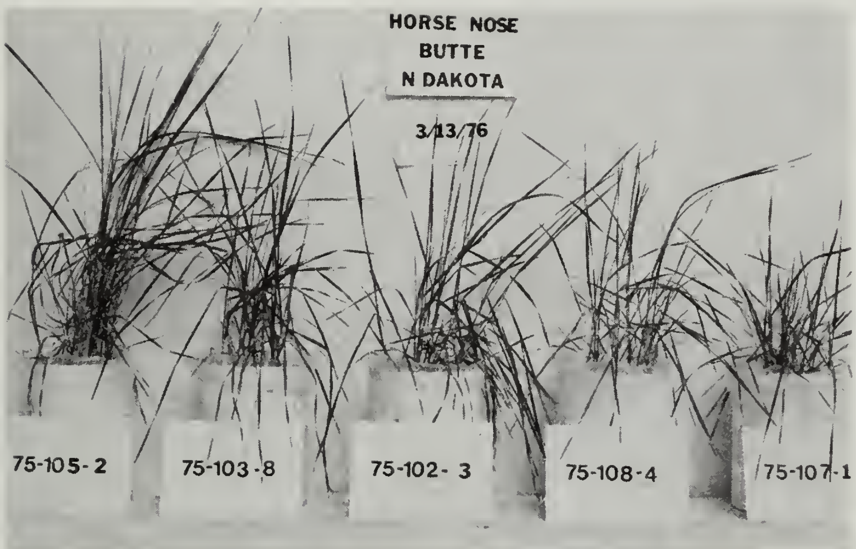
0 - no salt crust present
1 - 1-30 percent of surface area covered with salt crust
2 - 31-60 percent of surface area covered with salt crust
3 - 61-90 percent of surface area covered with salt crust
4 - 91-100 percent of surface area covered with salt crust

Blackened leaf tips were observed and frequency of occurrence, within pots, was recorded as follows:

0 - no plants with black leaf tips
1 - 1-4 plants with black leaf tips
2 - 5-8 plants with black leaf tips
3 - 9-12 plants with black leaf tips
4 - 13-16 plants with black leaf tips

These blackened leaf tips (5-10 mm) changed to a brown color after 1-2 weeks. Although the leaf tips died back, there was no evidence of overall yield reduction of plants so affected.

Roman numerals I and II in Table 37, Appendix F, refer to replications. Duplicate pots were run on all soil and bedrock samples for which there was adequate soil material.



PHOTOGRAPH 7 - Range in Western Wheatgrass Growth on Overburden Samples from the Horse Nose Butte Study Area

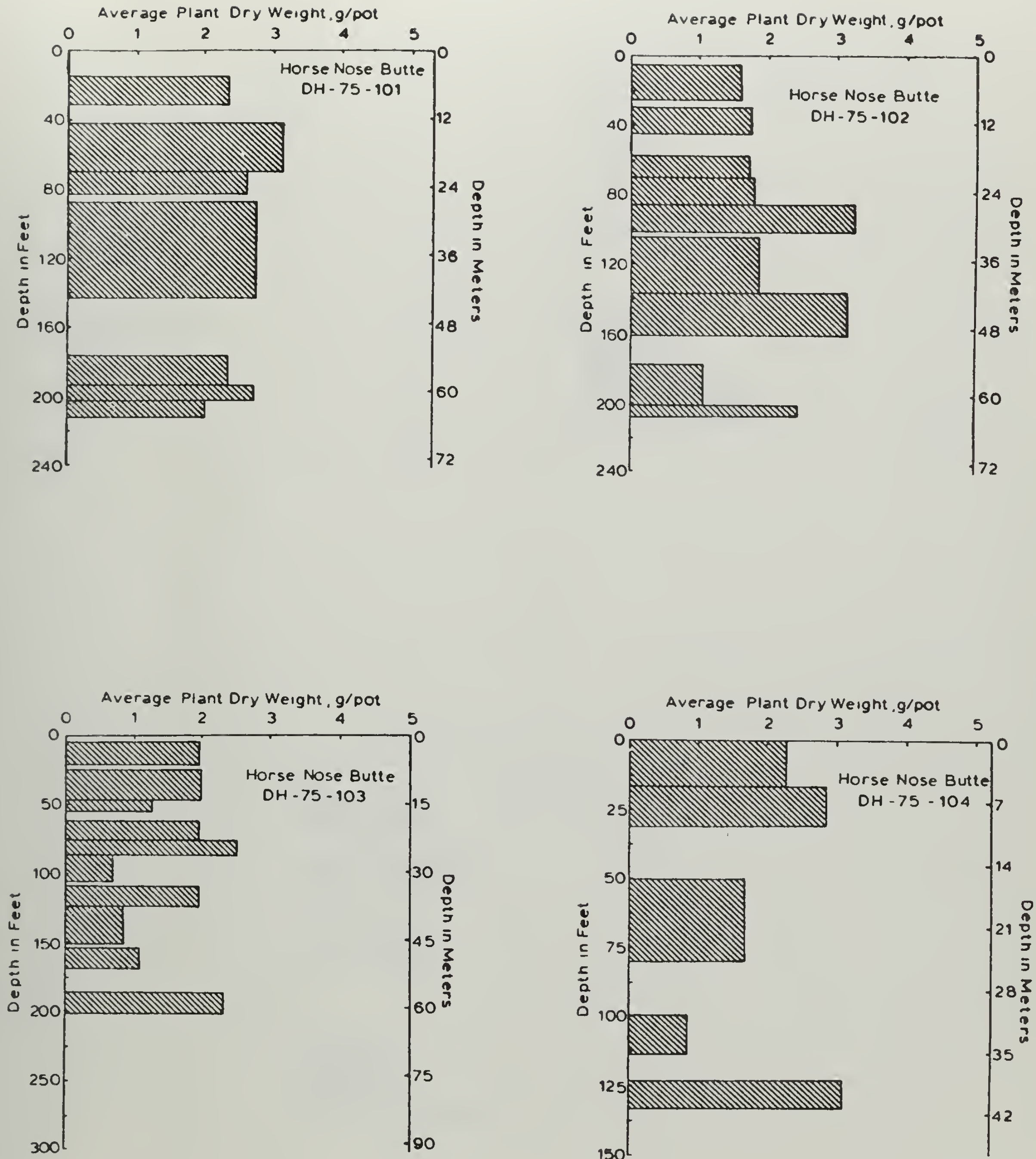


Figure 20. Yields of western wheatgrass on bedrock samples from Drill Holes 75-101 through -104, Horse Nose Butte Study Area, North Dakota

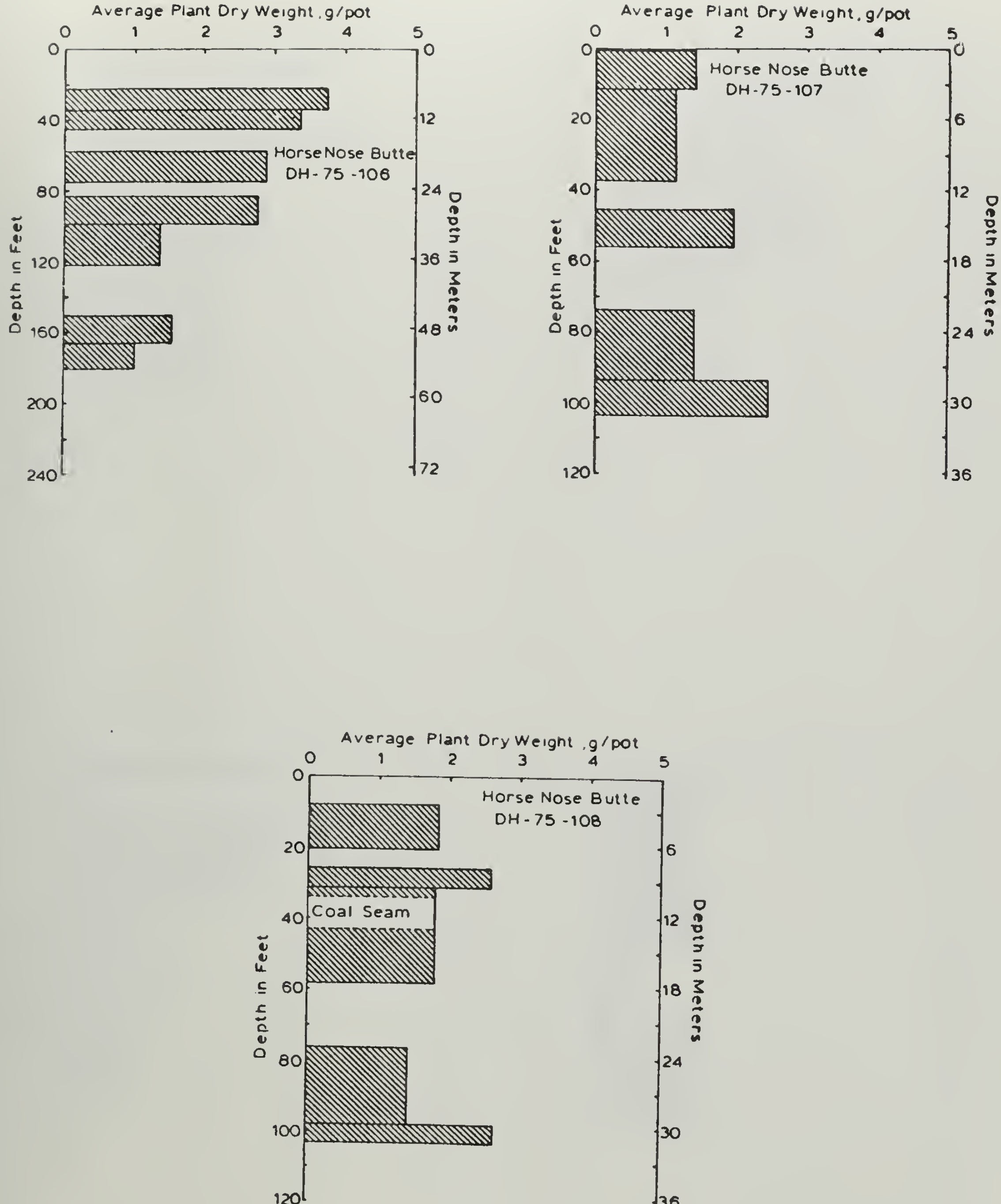


Figure 21. Yields of western wheatgrass on bedrock samples from Drill Holes 75-106 through -108, Horse Nose Butte Study Area, North Dakota

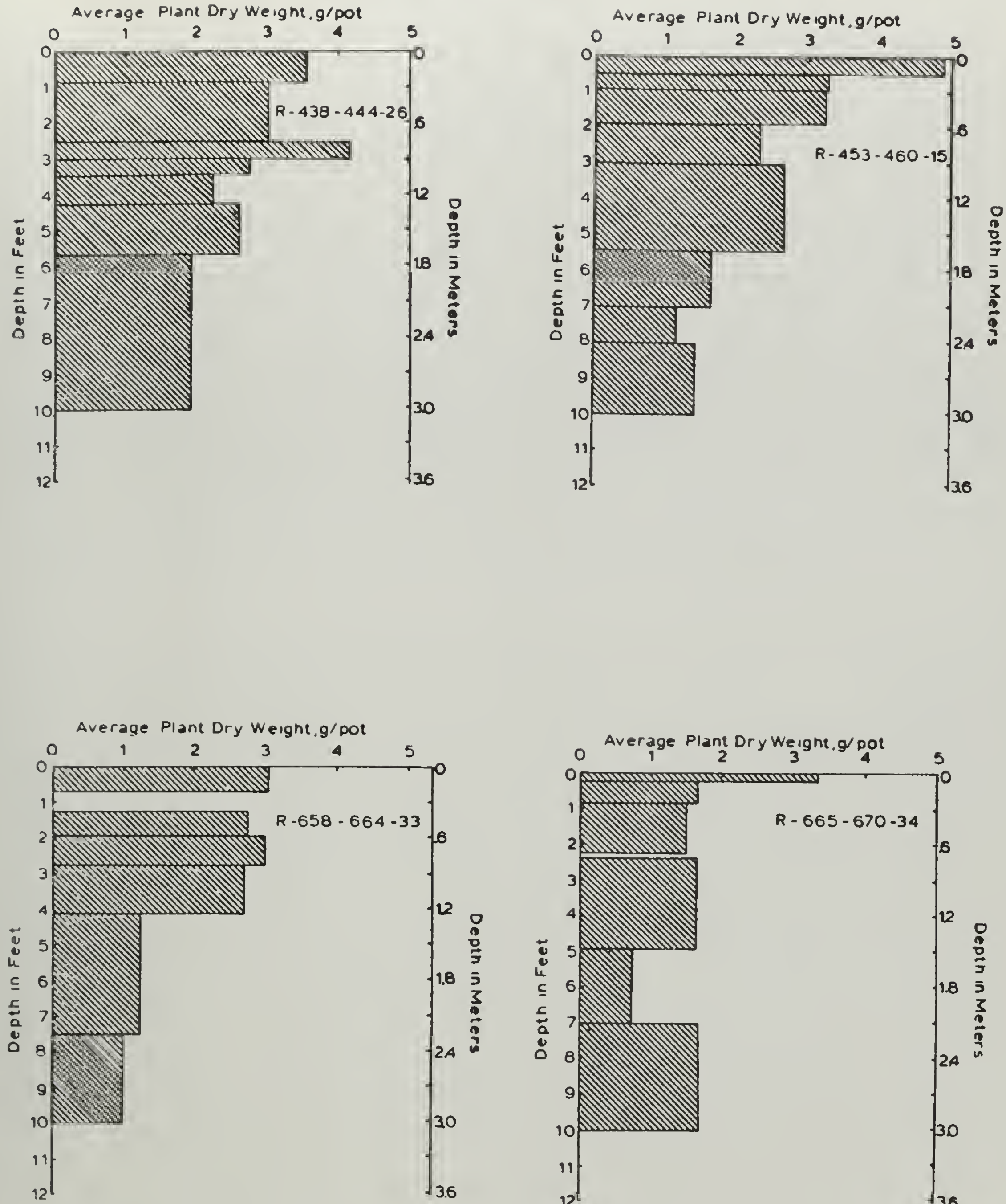


Figure 22. Yields of western wheatgrass on soil profile samples from the Horse Nose Butte Study Area, North Dakota

Additional Data

Blackening of the leaf tips was observed on various samples. This blackening of the leaf tips was hypothesized to be boron toxicity, but work done by Bureau of Reclamation personnel in Billings, Montana, showed that there was no correlation between the amount of hot water soluble boron and the amount of blackened leaf tips.

In some cases, sufficient soil material was not available for the desired sample weight of 2.0 kg. It was not known whether significant yield decreases would result from these samples. Three soils with five sample weights (2.0, 1.9, 1.8, 1.6, and 1.4 kg) were tested following the previously described greenhouse procedures. The results of an analysis of variance (AOV) showed that there were significant differences in yields between the sample weight (0.001 level). Since the AOV showed there were significant differences, a Duncans Multiple Range test was conducted. Results of this test showed that there were significant differences in yield at the 5 percent level between all sample weights except 2.0 versus 1.9 kg; 1.9 versus 1.6 kg; and 1.6 versus 1.4 kg. This shows that for statistical comparison purposes, a sample weight of 1.9 or 2.0 kg is needed for this study.

ALTERNATE OBJECTIVES OF RECLAMATION

Three reclamation objectives and nonmining were considered as possible alternatives for the Horse Nose Butte Study Area. Because of the need for energy and indications that the area could be reclaimed if surface mined, the nonmining option was considered unacceptable.

Objective No. 1 would require mining plans that return the surface mined area to the present condition or at least as near as possible to present conditions. This objective is not practical under present mining practices and it is also doubtful this objective would meet the desires of the agricultural community. Physically, the present topographic conditions could be recreated but revegetation and stabilization of disturbed material with similar relief and exposures in a short time (3 to 7 years) is near impossible.

Mining plans to meet Objective No. 2 would provide for stripping and stockpiling suitable material for surfacing shaped spoils with a uniform depth of similar material. This objective can be met and would generally be accepted. The reconstructed profiles can be revegetated and should stabilize with the climate readily. It is also the most economically feasible objective.

Using applicable methods described under Recommendations for Reclamation, material for surfacing reshaped spoils would be stripped and stockpiled. The quantity of top dressing and subsurface material would usually be limited to the amount of good quality material available in each tract being stripped or 5 feet. Profile improvement would be limited to tracts with numerous shale and till outcrops with a very thin soil mantle, and tracts with solenetz and solodized solonetz soils. Tracts with deep soil would have a reduced agricultural potential. This objective is easily attainable in the Horse Nose Butte area and will satisfy the environmental requirements for revegetation.

Objective No. 3 would require mining plans that would make the best use of all suitable material. Areas deficient in surfacing material would be improved by borrowing material from deep soil areas. The idealized objective would reconstruct profiles in most areas that would be capable of maximum agricultural productivity attainable in this climatic area. Legal limitations on transporting material across ownership lines, distance from deficient tracts to available material, and overall economic limitations will prevent attainment of the idealized conditions.

Reclamation and revegetation plans for the Horse Nose Butte Study Area should consider combination of Objectives Nos. 2 and 3. Present productive capacity of the better dry farmed land would be retained and many tracts of low quality range land would be improved.

RECLAMATION PROBLEMS AND RECOMMENDATIONS

Hydrology

The Horse Nose Butte site is located in a recharge area for the shallow local ground water flow system. Due to the low permeability and small thickness of sandstone beds, the study area contains no major shallow aquifers. Fracture zones in the lignite will supply small amounts of water to farm wells, but the lignite beds generally are not significant aquifers. Ground water flow from the study area is toward lowland areas along Spring Creek and its tributaries.

Under the most adverse postmining conditions, water and oxygen moving through the planned mine spoil banks could react with pyrite and form sulfuric acid which could react with calcite and dolomite contained in the aquifer matrix, resulting in a calcium-magnesium sulfate type water. Generally the dissolved-solids concentration would be below 6,500 mg/l. Ion exchange on clay materials will produce a sodium sulfate water type that will move downgradient toward discharge areas. Gypsum present in the spoil banks could be readily dissolved and could cause an increase in the sulfate content in the ground water downgradient from mine sites. The foregoing most adverse condition should not occur in this study area. North Dakota law requires stripping, stockpiling and placement of good quality material, if available, on reshaped spoils. There is adequate good quality material low in gypsum and with little or no pyrite for top dressing and subsurface material. This material should have the capability of storing the moisture from precipitation. Deep aquifers are protected from direct contamination from the mining by the relatively impervious Cannonball Member in the Fort Union Formation and by confining beds in the Hell Creek Formation.

Short-term geochemical effects will be limited to mine ponds and lakes at the mine site. If these surface water sources are discharged to tributaries of Spring Creek, an increase in dissolved solids will occur at low flow. The long-term geochemical effect will be an increase in dissolved solids in water from the local flow system downgradient from the mine site.

Small quantities of water are available from ground and surface water sources in the Dunn Center area; however, the only reliable water source for extensive reclamation is from the Little Missouri River area of Lake Sakakawea.

Continued monitoring before, during and after mining is necessary to determine changes in the hydrologic system.

Vegetation, Soil Water and Soil Detachability

All of the soils interact similarly with water, so a single family of linear relationships between moisture content and moisture retention force can be used to define the vegetation-soil-water relationships.

About 3 feet of the extensively occurring medium-textured (silt loam) soil are required to store the accumulated moisture from normal amounts of winter and spring precipitation under low runoff conditions. Greater depths of soil are required to store the precipitation during years that are wetter than normal.

On the uplands, highest yields of grasses occur where about 3 feet of relatively coarse soils overlie finer-textured soils. This causes part of the soil water to be "perched" and thus more readily available to plants. Appreciable depths of sandy loam materials that occur in some lowland areas would provide a source of relatively coarse material to place over finer-textured soil if it is desirable to increase the productivity of mid or tall grasses on the area after mining.

Susceptibility of the soils to erosion is moderate to high. Lowest detachability rates were measured on samples from the top 20 inches of the soils where concentrations of organic matter and roots were greatest. Replacement of these materials on the surface after mining would reduce erosion and retain the beneficial microbial population.

Topsoil materials tend to be compacted when they are replaced during the rehabilitation procedure. Some type of mechanical treatment to hold the water on the surface while it infiltrates, or a series of controlled irrigations by sprinkler would reduce this compaction and thus increase infiltration and permeability and reduce runoff and erosion.

Sediment Yield

There are numerous alternatives for which reclamation plans could be designed. The recommendations presented here assume that the objective is to return the land to premining uses and to about the level of premining productivity.

The values for the variables involved in predicting postmining sediment yields from the study area are difficult to determine until mining plans are available. Therefore, no attempt was made to assess specific postmining conditions. However, several considerations can be emphasized with regard to sediment yields, and general recommendations can be made which should minimize sedimentation associated with surface mining.

Under actual mining conditions, it can be expected that sediment control practices will vary with the locations selected to mine within the study area and the intensity of control will also vary--for example, problems associated with mining on a 15-percent slope will differ from those of mining in areas with 0 to 4 percent slopes.

During mining, the outer slopes of raw, ungraded overburden areas would be expected to yield sediment at rates of perhaps 10 or more times greater than those presently estimated for the study area. For areas being returned to rangeland, sediment yields rates, perhaps, will be two to five times greater than rates from present rangeland during the 4 or 5 years of rehabilitation period after reshaping, topsoiling and seeding of adapted native grasses. After this period and when the vegetation is fully established, water-stable soil aggregation is reestablished and the channels have stabilized, sediment yields rates should approximate the present rates. Sediment yield rates from areas returned to cropland, using topsoil, will also be greater than present rates until probable compaction is worked out of the soil and soil aggregation is reestablished. After that time the sediment yield rates from the cropland should approximate present rates.

Certain control measures during the mining and rehabilitation periods would prevent significant increases in sediment discharge to Slow Creek. Temporary reservoirs downstream from the mine area could be used to trap sediment. These may have to be cleaned periodically and perhaps it will be desirable to destroy the reservoirs and rehabilitate the sites after the rehabilitation period. Another alternative that may apply in certain locations would be to spread sediment-laden flows on relatively flat, grassy areas downstream from the mine (Miller et al., 1969). Close-spaced contour furrowing (Branson, Miller and McQueen, 1966) or gouger pitting (Sindelar et al., 1974) would minimize sediment yield from restored rangeland during the rehabilitation period and aid in establishing vegetation.

Design of the reconstructed drainage systems will be an important variable to consider in the rehabilitation planning process. It is imperative that drainageways be established as soon as feasible and that special methods be used to aid vegetation establishment in the drainage bottoms. Sediment yields would probably be minimized if the reconstructed drainage system included relatively wide valley bottoms, which would cause flows to be shallow and nonerosive, and permit sediment deposition from the flows.

Drainage from haul roads and other impervious areas should be prevented from concentrating into large, erosive flows. The cut and fill slopes along haul roads should be stabilized with grass, if possible, to prevent erosion. Any water that is discharged from the mine pits should be released as low to moderate flows to prevent possible erosion by head-cutting, particularly in small channels. It may be necessary to divert Slow Creek where it crosses the study area in section 3 (plate 26) and to impound flows of some tributaries during the mining period to prevent water from entering the mining area.

Surface Shaping and Revegetation

Successful revegetation of surface mined areas require: (1) stockpiling material, (2) shaping and placing of material, (3) planting and seedbed preparation, and (4) management of the revegetated area until the vegetation has been permanently reestablished. In North Dakota, the landowner's written preference for a land use plan covering his affected land must accompany the reclamation plan.

Stockpiling Material

Selection of material for topdressing reshaped spoils to the desired topography requires proper planning before mining, but the final selection of materials, methods of stripping and stockpiling will be accomplished during the actual mining process. As a first step, the A horizon and most of the B horizon could be stripped and stockpiled for topdressing. Plate 34 shows the depth of topdressing material and plate 33 shows the quality of this material. Conditions in the stockpile will differ from that of the inplace soil with regard to moisture, aeration, temperature and light. This will affect the naturally occurring cycles of the organisms present. Since biological activity is primarily confined to the solum where organic matter is present for a food source, proper storage is very important. Activity in the parent material is nil and storage can be accomplished with less risk of degradation.

Conclusive research has not been accomplished on topsoil stockpiles and their effect on biological activities, but some conclusions can be drawn. The effect on organisms will coincide with the state of the topsoil when stockpiled. Temperature and moisture would be more constant than in situ. Cold temperatures diminish biological activities. The size and depth of the pile could favor anerobic organisms over aerobic activities. Some nitrogen loss in the form of ammonia could occur. A dry cold soil will have little biological activity. Organisms associated with light would decrease.

No long-term effect on the soil biological ecosystem is expected. The reduced activity and number of organisms will return to normal after the soil is spread on reshaped spoils.

The texture of the material to be saved for topdressing and reclamation ranges from loam to clay loam. The topdressing material can be selectively stripped to produce a dark colored loam with over 2 percent organic matter. It would be an excellent media for grass indigeneous to the area or crops. This material is nonsaline, nonsodic and has less than 10 percent lime. Native fertility of the material is good.

It would be desirable, if economically feasible, to deep plow the land to the depth of the planned surface soil cut where possible. At this stage, stones could be removed and placed where they can be buried later.

The material for topdressing can then be removed and stockpiled or spread on shaped spoils. Surface soil suitable for substratum use can be removed and stockpiled. Unsuitable surface soil, subsoil, and substratum would be deep buried with the spoil.

The second step would be the removal of suitable substrata for stockpiling or placement on shaped spoils. The depth of this material will range from 0 to over 11 feet deep. Substrata not suitable for reclamation purposes would be handled with the spoil which will be deeply buried. Plates 35 and 36 show the amount and quality of the substrata. Control of stockpiling practices is necessary to assure segregation of material of contrasting textures such as sandy loam, loamy sand, or sand from finer textured material. These materials should not be randomly mixed with clay loam or finer textures; however, planned mixing to a homogenous mass may be desirable. Placement of contrasting textures in a stockpile or a soil profile affect moisture movement and may cause lateral water movement and zones of saturation. The sandy substratum materials would be best for placing in the same profile to depths of 3 feet or greater. Stockpiles should be planned to hold erosion to minimal levels.

Thin coal seams occur sporadically in the site within the material that may be stripped and stockpiled. The coal is usually acid and should be separated from the stockpiled material or mixed with alkaline material. Mixing to minimize the acidity appears feasible.

Shaping and Placing Material

The present topography of the site ranges from nearly level to strongly rolling. The land use of the area will most likely revert primarily to cropland with a minor amount of grazing land. For these purposes and for erosion control and drainage, the land should be reclaimed to as gentle a grade as possible. Slopes ranging from nearly level to less than 4 percent would be optimum. This would increase the possibility of deeper soil profile development, reduce erosion, increase infiltration of rainwater, permit a desirable field layout, and would increase the productivity of the land. Reconstructed slopes should be long, smooth and blend in with the surrounding terrain. Slopes should be planned to provide drainage for adjacent areas which now naturally drain through the site as well as drainage of the specific site area.

Prior to spreading of stockpiled material over the shaped spoils or placed substratum, the material should be chiseled with a plow to provide a broken and open surface so topdressing material and substratum material will be in good contact. This will facilitate air, water, and root movement from horizon to horizon and eliminate compacted layers. A loss of contact between layers could restrict water movement which could reduce plant growth. The profile development process would be delayed.

Elements generally considered toxic include selenium, arsenic, molybdenum, fluoride, boron, lead, mercury, and barium. Quantitative analysis for these elements was not performed, but there was no evidence that these elements occur in the area in harmful amounts.

Saline or saline sodic material (comprised most generally of chlorides and sulfates of calcium, magnesium and sodium) should be placed below 3 feet in reconstructed profiles. However, it may be placed nearer the surface if adequate higher quality material is not available and the water movement potential is adequate for leaching. Sodic material is more harmful in the surface layer than in the substratum as it prevents infiltration of water into the soil profile and surface crusting occurs. This sodic material increases the erosion hazard. If sodic substratum must be used, it may be feasible to apply gypsum before the topdressing is placed.

Planting and Seedbed Preparation

Prior to seeding in the first year of reclamation, the surface soil should be plowed with a chisel plow in two directions and harrowed. Two operations with the drag harrow may be necessary for adequate seedbed preparation. If fertilizer is needed, it should be spread prior to the second dragging operation. The rate of application and fertilizer type should be based on soil tests and recommendations of the Extension Service. A mixture of 4 pounds of intermediate wheatgrass, 3 pounds of tall wheatgrass, 3 pounds of alfalfa, and 1 pound of sweetclover per acre should be considered for a precropland vegetative site. Small grains sown at the rate of one-fourth bushel per acre can be seeded as a companion crop. Planting should be done with a press drill.

The reconstructed lands that are suitable for a grassland regime only should be prepared and fertilized in a manner similar to lands that will be cultivated after revegetation. One suggested mixture consists of 2 pounds of pubescent or intermediate wheatgrass, 2 pounds of blue grama and 2 pounds of tall wheatgrass per acre should be seeded with a press drill. This land should also be protected from grazing during the initial 3-year period, then controlled grazing should be practiced.

Almost any soil element is toxic when it is present in abnormally high concentrations. Such abnormalities may be natural to the material or applied as salts in fertilizer, insecticides, or fungicides. Effect of fertilizer, insecticides, or fungicides are nil in the specific study area.

Management

Natural rainfall is adequate in the spring and often in the fall of the year for establishment of a vegetative cover; therefore, supplemental irrigation for vegetative establishment is not proposed. Irrigation should be used to salvage newly seeded areas if precipitation is below normal. If irrigation is used for the initial vegetative establishment, the source of water should be checked in regard to quality. Water containing abnormal high quantities of sodium or higher E.C. values should not be used. Water with a SAR of under 10 and E.C. values under 1,000 are preferable.

Most areas of reclaimed land on the Horse Nose Butte area will be underlain with sodic and saline material below 3 feet. The upper 3 feet will be chemically suitable for irrigation; but this sodic substratum material will be slowly permeable. The area would not be self draining. The potential movement of water into subsurface drains is low. Therefore, sustained irrigation should not be proposed for this area because the chemical and physical data indicate a desirable salt balance could not be achieved in the lower horizons. Subsurface drainage costs would be excessive.

Grazing or other use of the established vegetation should be deferred for a period of 3 years. Subsidence of the material should take place during this time. After this period the land could be used for cultivated crops or pasture as the operators needs dictate. Conservation planning can be carried out in cooperation with the local office of the Soil Conservation Service.

BIBLIOGRAPHY

American Society for Testing and Materials, 1974, Standard specifications for classification of coals by rank /ASTM designation D388-66 (reapproved 1972)/, in Gaseous fuels; coal and coke; atmospheric analysis: Am. Soc. Testing Materials, pt. 26, p. 54-58.

Aresco, S. J., Haller, C. P., and Abernethy, R. F., 1960. Analyses of tipple and delivered samples of coal (collected during the fiscal year 1959): U.S. Bur. Mines Rept. Inv. 5615, 59 p.

Benson, W. E., 1952, Geology of the Knife River area, North Dakota: U.S. Geological Survey open-file report.

Branson, F. A., Miller, R. F., and McQueen, I. S., 1966, Contour furrowing, pitting, and ripping on rangelands of the western United States: Jour. Range Management, v. 19, p. 182-190.

Croft, M. G., 1973, Ground-water resources Mercer and Oliver Counties, North Dakota: North Dakota Geol. Survey Bull. 56, pt. III, and North Dakota State Water Comm. County Ground Water Studies 15, pt. III, 79 p.

Crosby, O. A., 1970, A proposed streamflow data program for North Dakota: U.S. Geol. Survey open-file report, 68 p.

Crosby, O. A., 1975, Magnitude and frequency of floods in small drainage basins in North Dakota: U. S. Geol. Survey Water-Resources Inv. 19-75, 24 p.

DeCarlo, J. A., Sheridan, E. T., and Murphy, Z. E., 1966, Sulfur content of United States coals: U.S. Bur. Mines Inv. Circ. 8312, 44 p.

Denson, N. M., and Gill, J. R., 1965, Uranium bearing lignite and carbonaceous shale in the southwestern part of the Williston basin--a regional study: U.S. Geol. Survey Prof. Paper 463, 75 p.

Dingman, R. J., and Gordon, E. D., 1954, Geology and ground-water resources of the Fort Berthold Indian Reservation, North Dakota: U.S. Geol. Survey Water-Supply Paper 1259, 115 p.

Fieldner, A. C., Rice, W. E., and Moran, H. E., 1942, Typical analyses of coals of the United States: U.S. Bur. Mines Bull. 446, 45 p.

Francis, Wilfrid, 1961, Coal, its formation and composition: London, Edward Arnold (Publishers) Ltd., 806 p.

Frickel, D. G., Shown, L. M., Patton, P. C., 1975, An evaluation of hillslope and channel erosion in the Piceance Basin, Colorado: Colo. Water Conserv. Board Water Resources Cir. 30, 37 p.

Gardner, R., 1945. "Some Soil Properties Related to the Sodium Salt Problem in Irrigated Soils." U.S. Department of Agriculture Technical Bulletin 902

Jenson, Ray E., "Climate of North Dakota."

Kellogg, Charles E., 1962. "The Place of the Laboratory in Soil Classification and Interpretation." U.S. Department of Agriculture, Soil Conservation Service

Klausing, R. L., 1976, Ground-water basic data for Dunn County, North Dakota: North Dakota Geol. Survey Bull. 68, pt. II, and North Dakota State Water Comm. County Ground-Water Studies 25, pt. II, 501 p.

Landis, E. R., 1973, Coal, in Mineral and Water Resources of North Dakota, North Dakota Geol. Survey Bull. 63, p. 45-52.

Lowry, H. H., ed., 1945, Chemistry of coal utilization, Volumes I and II: New York, John Wiley and Sons, Inc., 1868 p.

Lowry, H. H., 1963, Chemistry of coal utilization, supplementary volume: New York, John Wiley and Sons, Inc., 1142 p.

McQueen, I. S., 1961, Some Factors Influencing Streambank Erodibility: U.S. Geol. Survey Prof. Paper 424B, p. 28-29.

McQueen, I. S., and R. F. Miller, 1968, Calibration and evaluation of a wide-range gravimetric method for measuring moisture stress: Soil Sci., v. 106, p. 225-231

McQueen, I. S., and R. F. Miller, 1974, Approximating soil-moisture characteristics from limited data: Emperical evidence and tentative model: Water Resources Research, v. 10, p. 521-527.

Michurin, B. N., and I. A. Lytayev, 1967, Relationship between moisture content, moisture tension, and specific surface area in soil: Soviet Soil Sci., v. 8, p. 1093-1103.

Miller, R. F., I. S. McQueen, F. A. Branson, L. M. Shown, and William Buller, 1969, An evaluation of range floodwater spreaders: Jour. of Range Management, v. 22, p. 246-257.

Miller, R. F., and I. S. McQueen, 1972, Approximating recurring moisture relationships in desert soils: Eco-Physiological Foundation of Ecosystem Productivity in Arid Zone: Publishing House NAUKA Leningrad USSR p. 119-122.

Moore, E. S., 1940, Coal, its properties, analysis, classification, geology, extraction, uses and distribution: New York, John Wiley and Sons, Inc., 473 p.

Omodt, Schroer, Patterson, 1975, "The Properties of Important Agricultural Soils as Criteria for Mined Land Reclamation."

Pacific Southwest Inter-Agency Committee, 1968, Report on factors affecting sediment yield in the Pacific Northwest area: Water Management subcommittee, Sedimentation Task Force, 10 p.

Peters, William B., 1975. "Economic Land Classification for the Prevention and Reclamation of Salt-Affected Lands." Paper presented at United Nations Food and Agriculture Organization Conference on Salt-Affected Soils. U.S. Bureau of Reclamation, Denver, Colorado

Richards, L. A., and others, 1954, Diagnosis and improvement of saline and alkali soils: U.S. Dept. Agr. Handbook 60, 160 p.

Sandoval, F. M., Bond, J. J., Power, J. F., and Willis, W. O., 1973, Some environmental aspects of strip mining in North Dakota: North Dakota Geol. Survey Educ. Ser. 5, 121 p.

Schofield, R. K., 1935, The pF of the water in the soil: Internat. Congress Soil Sci. 3rd Trans. v. 2, p. 37-48.

Schopf, J. M., 1956, A definition of coal: Econ. Geology, v. 51, no. 6, p. 521-527.

Schopf, J. M., 1960, Field description and sampling of coal beds: U.S. Geo. Survey Bull. 1111-B, 70 p.

Schopf, J. M., 1966, Definitions of peat and coal and of graphite that terminates the coal series (Graphocite): Jour. Geology, v. 74, no. 5, pt. 1, p. 584-592.

Shown, L. M., R. F. Miller, and F. A. Branson, 1969, Sagebrush conversion to grassland as affected by precipitation, soil, and cultural practices: Jour. of Range Management, v. 22, p. 303-311.

Shown, L. M., 1970, Evaluation of a method for estimating sediment yield: U.S. Geol. Survey Prof. Paper 700-B, p. B245-B249.

Sindelar, B. W., and others, 1974, Surface mined land reclamation research at Colstrip, Montana: Progress report 1973-74, Mont. Agr. Expt. Sta. Research Rept. 69, Mont. State Univ., Bozeman, Mont., 98 p.

Snyder, N. H., 1950, Handbook on coal sampling: U.S. Bur. Mines Tech. Paper 133 (revised), 10 p.

Stanton, T. W., 1920, The fauna of the Cannonball marine member of the Lance Formation: U. S. Geol. Survey Prof. Paper 128-A, p. 1-60.

Strahler, A. N., 1952, Dynamic basis of geomorphology: Geol. Soc. Am. Bull. 63, p. 923-938.

Swanson, V. E., Huffman, Claude, Jr., and Hamilton, J. C., 1974, Composition and trace-element content of coal, Northern Great Plains area: Contribution to Mineral Resources Work Group, Northern Great Plains Resource Program.

Taylor, S. R., 1964, Abundance of chemical elements in the continental crust--a new table: Geochim. et Cosmochim. Acta, v. 28, no. 8, p. 1273-1285.

Tomkeieff, S. I., 1954, Coals and bitumens and related fossil carbonaceous substances: London, Pergamon Ltd., 122 p.

Truesdell, A. H., and Jones, B. F., 1974, Water, a computer program for calculating chemical equilibria of natural waters: U. S. Geol. Survey Jour. Res., v. 2, no. 2, p. 233-248.

U.S. Bureau of Mines, 1965, Bituminous coal, in Mineral facts and problems, 1965, p. 119-147.

U.S. Department of Agriculture, 1941, Climate and man: Year Book of Agriculture, 1,248 p.

USDA Soil Conservation Service 1968 "Soil Survey of Stark County, North Dakota."

USDA Soil Conservation Service 1975 "Soil Survey of Oliver County, North Dakota."

U.S. Department of Commerce, 1973, Monthly normals of temperature, precipitation, and heating and cooling degree days 1941-70: U.S. Dept. of Commerce, Climatology of the United States, no. 81 (North Dakota)

U. S. Geological Survey, 1975, Geochemical survey of the western coal regions; Second annual progress report, July 1975: U.S. Geol. Survey open-file report 75-436, 132 p.

ENGLISH TO METRIC (SI) CONVERSIONS

A dual system of measurements--English units and the International System (SI) of metric units--is given in this report. SI is a consistent system of units adopted by the Eleventh General Conference of Weights and Measures in 1960. Selected factors for converting English units to SI units are given below.

Multiply English units	By	To obtain SI units
Inches	25.40	millimeters (mm)
	2.54	centimeters (cm)
	0.254	decimeters (dm)
	0.0254	meters (m)
Feet	0.3048	meters (m)
Miles	1.609	kilometers (km)
Pounds	453.60	grams (g)
Ton	0.9072	tonne (t)
Acres	0.4047	square hectometers (hm^2)
	0.004047	square kilometers (km^2)
Square miles	2.590	square kilometers (km^2)
Cubic inches	16.39	cubic centimeters (cm^3)
Gallons	.003785	cubic meters (m^3)
Acre-feet	.001233	cubic hectometers (hm^3)
Feet per mile	0.1894	meters per kilometer (m/km)
Inches per hour	2.54	centimeters per hour (cm/h)
Feet per day	.3048	meters per day (m/d)
Pounds per square inch	70.31	grams per square centimeter (g/cm^2)
Atmospheres	1033.27	grams per square centimeter (g/cm^2)
Bars	1019.78	grams per square centimeter (g/cm^2)
Pounds per cubic foot	0.01602	grams per cubic centimeter (g/cm^3)
Pounds per acre	1.1206	kilograms per square hectometer (kg/hm^2)
Feet squared per day	0.0929	meters squared per day (m^2/d)
Cubic feet per second	0.02832	cubic meters per second (m^3/s)
Gallons per minute	0.06309	liters per second (l/s)
Cubic feet per second per square mile	0.01093	cubic meters per second per square kilometer [$(m^3/s)/km^2$]
Pounds per square yard per hour	0.5426	kilograms per square meter per hour ($kg/m^2/h$)
Pounds per square foot per hour	4.8827	kilograms per square meter per hour ($kg/m^2/h$)
Btu per pound mass	2327.8	joules per kilogram (J/kg)
Degree Fahrenheit	$Tc = \frac{Tf-32}{1.8}$	degrees Celsius (°C)

APPENDIX A

GEOLOGY

7-1337 (9-69) Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: North Dakota
HOLE NO. DH 75-101 — LOCATION: 2280' W. of SE Corner, Section 14, T. 144 N., R. 94 W. — GROUND ELEV.: Altimeter 2328± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 9/24/75 — FINISHED: 10/2/75 — TOTAL DEPTH: 218.6 — BEARING: --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 141.0' 11/4/75 (2187.0') — LOGGED BY: Taucher — LOG REVIEWED BY:

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole started 9/24/75. Nx drive samples 0 to 15.0'. Set 6" Cs to 14.5'. 2-3/4" wire line core 15.0 to 24.0'. Lost drill water 15.0 to 19.0'. Advanced 6" Cs to 19.5'. Washed away part of sample 15.0 to 24.0'.

Hole at 24.0' 9/25/75. 6" Cs at 19.5'. W.L. at 13.8'. 2-3/4" wire line core 24.0 to 63.2'. Dropped parts of 41.1 to 52.3 & 52.3 to 63.2 samples using revert.

Hole at 63.2' 9/26/75. 6" Cs at 19.5'. W.L. at 11.2'. 2-3/4" wire line core 63.2 to 83.7'. Core 71.5 to 73.2' dropped in hole. Lost sample in overdrill. Dropped sample 73.2 to 83.7'. Pulled wire line. Nx drive sample 73.2 to 83.7'. Recovered 6.1' of core. Using revert.

Hole at 83.7' 9/29/75. 6" Cs at 19.5'. W.L. at 18.2'. Modified core spring. 2-3/4" wire line core 83.7 to 103.3'. Dropped some core from bottom of runs 88.7 to 93.2 & 93.2 to 96.4'. Lost in redrill. Using revert.

Soils analysis samples:

Sample	From (ft)	To (ft)
#1	0	5.0
#2	5.0 & 13.4	10.0 & 15.0
#3	15.0	31.7
#4	41.1	70.2
#5	70.2	82.7

Classification and physical condition:

0-5.0 SILTY TO CLAYEY SAND: Brown & slightly organic 0 to 0.5'; tan & calcareous 0.5 to 5.0'; dry; approximately 35% very low plasticity fines & 65% fine, uniform sand; wind blown (SM to SM-SC)

SENTINEL BUTTE FORMATION - PALEOCENE

5.0-10.0 SHALE: Brown to dark gray; oxidized; damp; firm; trims by knife with difficulty; plastic; broken.

10.0-13.4 LIGNITE: Black to dark brown; broken; moist.

13.4-15.0 SILTY SHALE: Brown to dark gray; oxidized; moist; firm; trims by knife with difficulty; moderately plastic to plastic.

15.0-31.7 SANDSTONE: Light gray; moist; compact; very fine grain, silty sandstone 15.0 to 24.0' (crushes easily between fingers); fine grain, clean uncemented sandstone 24.0 to 31.7' (like river sand); oxidized with clay contamination 23.5 to 24.0 & 31.5 to 31.7'; core lengths 1 to 3" 15.0 to 24.0'; pulverized 24.0 to 31.7'.

31.7-33.1 SHALE: Brown to dark gray; oxidized; moist; firm but cuts easily with knife; 50° slickensides at 32.4 & 32.8'; core lengths 3 to 6".

33.1-41.1 LIGNITE: Black to dark brown; dark brown zones appear to contain clay contamination; moderately hard.

41.1-70.2 SILTSTONE, SANDSTONE & SHALE: Material is laminated to thin-bedded with alternating layers of medium gray silty shale & light gray siltstone & sandstone; moist; moderately soft; cuts easily with knife; core lengths 3 to 18";
- 41.1-51.3 - mostly low plasticity clayey siltstone which crumbles easily between fingers.
- 51.3-52.6 - mostly very fine grain, silty sandstone with soft silty shale laminations; crumbles easily between fingers.
- 52.6-61.3 - moderately plastic silty shale which trims easily with knife; cemented claystone concretion 59.0 to 59.5'.
- 61.3-67.7 - mostly very fine grain silty sandstone with soft, silty shale stringers; crumbles easily between fingers.
- 67.7-70.2 - mostly moderately plastic silty shale with laminations of clayey siltstone; trims easily with knife; hard, claystone concretion 69.5 to 69.9'.

EXPLANATION — CORE LOSS / CORE RECOVERY

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: N. Dakota — SHEET 1 OF 3 — HOLE NO. DH 75-101

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: North Dakota
HOLE NO. DH 75-101 — LOCATION: 2280' W. of SE Corner, Section 14, T. 144 N., R. 94 W. — GROUND ELEV.: Altimeter 2328± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 9/24/75 — FINISHED: 10/2/75 — TOTAL DEPTH: 218.6 — BEARING: --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 141.0' 11/4/75 (2187.0') — LOGGED BY: Taucher — LOG REVIEWED BY:

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole at 103.3' 9/30/75. 6" Cs at 19.5'. W.L. at 19.9'. 2-3/4" wire line core 103.3 to 143.3'. Lost core from bottom of run 117.9 to 123.3'. Using revert.

Hole at 143.3' 10/1/75. 6" Cs at 19.5'. W.L. at 21.6'. 2-3/4" wire line core 143.3 to 193.2'. Slight water loss during drilling.

Hole at 193.2' 10/2/75. 6" Cs at 19.5'. W.L. at 103.2'. 2-3/4" wire line core 193.2 to 218.6'. Pulled 6" Cs. Hole completed. Hole left open for U.N.D. study.

Soils analysis samples:

Sample	From (ft)	To (ft)
#6	87.3	146.2
#7	176.8 (minus lignite)	193.6
#8	193.6	202.5

Classification and physical condition:

70.2-70.9 LIGNITE: Black to dark brown; breaks along bedding planes.

70.9-74.2 SANDY SHALE: Medium gray; moist; moderately soft; cuts easily with knife; contains large amounts of very fine sand; could be clayey sandstone; core lengths 6 to 12".

74.2-82.7 CLAYEY SANDSTONE: Light gray; moist; soft; cuts easily with knife; very fine grain; [illegible] when reworked; several soft, silty shale streaks; core lengths 1 to 18".

82.7-85.4 SILTY SHALE: Medium gray; moist; moderately firm; cuts by knife with difficulty; plastic when reworked; air slacks; core lengths 4 to 14".

85.4-87.3 LIGNITE: Black to dark brown; 45° slickenside at 86.0 & 86.2'; 85° oxidized joint 86.2 to 87.1'; breaks along bedding planes.

87.3-146.2 SILTSTONE, SANDSTONE & SHALE: Material is laminated to thin-bedded with alternating layers of medium gray silty shale & light gray siltstone & sandstone; moist; soft; siltstone & sandstone crumbles easily between fingers; shales cut easily with knife; weak HCl reaction; core lengths 3 to 24".
- 87.3-88.2 - moderately plastic silty shale which trims easily by knife.
- 88.2-100.0 - mostly laminated, soft clayey to sandy siltstone; includes silty shale & silty to clayey sandstone laminations.
- 100.0-115.0 - mostly silty, fine grain sandstone with laminations of silty shale & clayey siltstone; contains more silty shale with depth.
- 115.0-132.9 - mostly moderately firm shale or silty shale with laminations of silty, fine grain sandstone & clayey siltstone; alternating silty sandstone & shale 129.0 to 130.5'.
- 132.9-146.2 - mostly clayey to silty, very fine grain sandstone with laminations of silty shale; soft with firm zone 133.0 to 136.0'.

146.2-152.1 LIGNITE: Broken; hard; brea[illegible] along bedding planes.

152.1-152.4 CARBONACEOUS SHALE: Dark gr[illegible]; lignite; plastic; soft; cuts easily wit[illegible] knife.

152.4-153.4 LIGNITE: Contains thin streaks of lignite shale.

153.4-157.9 SHALE: Light gray; moist; firm; cuts by knife with difficulty; very plastic; few lignite fragments; core lengths 12±".

EXPLANATION — CORE LOSS / CORE RECOVERY

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: N. Dakota — SHEET 2 OF 3 — HOLE NO. DH 75-101

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: N. Dakota
HOLE NO. DH 75-101 — LOCATION: 2280' W. of SE Corner, Section 14, T. 144 N., R. 94 W. — GROUND ELEV.: Altimeter 2328± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 9/24/75 — FINISHED: 10/2/75 — TOTAL DEPTH: 218.6 — BEARING: --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 141.0' 11/4/75 (2187.0') — LOGGED BY: Taucher — LOG REVIEWED BY:

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

5 pound Lignite samples taken at the following intervals: 10.0-13.4', 33.0-36.3, 36.3-39.6, 146.2-148.2, 148.2-151.2, 158.0-161.0, 165.0-168.0, 170.0-172.8, 173.3-176.3, 212.5-215.0

11/4/75 W.L. 141.0' below ground surface. Gravel packed around plastic pipe (pipe installed by U.N.O.). Cleaned up drill site.

Soils analysis samples:

Sample	From (ft)	To (ft)
#9	202.5	212.1

Classification and physical condition:

157.9-176.8 LIGNITE: Black to dark brown; hard; wet; occasional vertical oxidized fracture; broken 162.4 to 163.4'; lignitic siltstone 176.3 to 176.8'.

176.8-179.7 SHALE: Medium gray; moist; plastic; firm; difficult trimming with knife; air slacks; lignitic inclusions 179.2 to 179.7'; horizontal slickenside 179.2 to 179.7'; core lengths 6 to 12".

179.7-180.9 LIGNITE: Black to dark brown; hard; core lengths 2 to 6".

180.9-193.6 SHALE: Medium gray; moist; firm; trims by knife with some difficulty; plastic; air slacks in zones; dark gray to black lignitic shale 182.8 to 183.0'; lignite 184.3 to 184.6, 185.1 to 185.4 & 190.7 to 190.8'; hard, cemented, claystone concretion 189.5 to 189.8'; low to moderately plastic, laminated silty shale 191.0 to 193.6'; 65° fracture at 184.5'; core lengths 6 to 18".

193.6-202.5 SILTY SANDSTONE: Light gray; moist; compact; uncemented; silty; very fine grain (near silt); trace of clay; laminated in zones; crumbles easily between fingers; slightly calcareous; grading into siltstone 202.2 to 202.5'; 1/4" marcasite nodule at 198.0'; core lengths 12 to 18".

202.5-212.1 SILTY SHALE: Medium gray; moist; firm; trims easily with knife; air slacks in places; moderately plastic to plastic; thin-bedded with laminated zones; hard limestone 203.4 to 204.2 & 207.3 to 207.4'; ¼ to ½" marcasite nodules along 60° slickenside at 210.1'; 2 opposing 50° fractures at 211.9'; core lengths 2 to 12".

212.1-215.5 LIGNITE: Black; hard.

215.5-218.6 SILTY SHALE: Light gray; moist; moderately firm; trims easily with knife; moderately calcareous; thin-bedded; very soft siltstone (crumbles easily between fingers) 216.5 to 217.3'; air slacks in zones; core lengths 6 to 12".

EXPLANATION — CORE LOSS / CORE RECOVERY

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: N. Dakota — SHEET 3 OF 3 — HOLE NO. DH 75-101

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

GEOLOGIC LOG OF DH 75-101

GEOLOGY: G. TAUCHER — SUBMITTED:
DRAWN: — RECOMMENDED:
CHECKED: — APPROVED:

BILLINGS, MONT. — MAY 1976 — 1305-600-83

GEOLOGIC LOG OF DRILL HOLE

7-1337 (9-69) Bureau of Reclamation — SHEET 1 OF 3

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: North Dakota

HOLE NO.: DH 75-102 — LOCATION: 1930' E. & 2670' N. of SW. Corner Section 15, T. 144 N., R. 94 W. — GROUND ELEV.: Altimeter 2350± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 10/3/75 — FINISHED: 10/10/75 — TOTAL DEPTH: 208.7 — BEARING: --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 168.3' 11/4/75 (2181.7') — LOGGED BY: Taucher — LOG REVIEWED BY:

Column headings: NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS | TYPE AND SIZE OF HOLE | CORE RECOVERY (%) | SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM / TO | SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE / LIMITED SUITABILITY / UNSUITABLE | ELEVATION (FEET) | DEPTH (FEET) | GRAPHIC LOG | SAMPLES FOR TESTING | CLASSIFICATION AND PHYSICAL CONDITION

Notes on drilling conditions:

Hole started 10/3/75. Nx drive samples 0 to 15.0'. 2-3/4" wire line core 15.0 to 24.4'. Set 6" Cs to 14.5'. Not using revert.

Hole at 24.4' 10/6/75. 6" Cs at 14.5'. Hole dry. 2-3/4" wire line core 24.4 to 63.6'. Slight water loss. Using revert.

Hole at 63.6' 10/7/75. 6" Cs at 14.5'. W.L. at 27.0'. 2-3/4" wire line core 63.6 to 132.8'. Slight water loss.

Core recovery (%): 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 98, 100, 100, 100, 98, 100, 100

Sample	From	To
#1	0	5.2
#2	5.2	25.0
#3	30.3	44.8
#4	53.7	69.6
#5	69.6	85.6
#6	85.6	101.3

Elevation (feet)	Depth (feet)
2344.8	5.2
2325.0	25.0
2322.4	27.6
2319.7	30.3
2305.2	44.8
2296.3	53.7
2280.4	69.6
2264.4	85.6
2261.4	88.6

Graphic log labels: A, B, C, D

Classification and physical condition:

0-5.2 SILTY SAND: Dark brown & slightly organic 0 to 1.4'; tan & calcareous 1.4 to 5.2'; dry; approximately 35% very low plasticity fines & 65% fine uniform sand; occasional pin-size root hole; few ¼ to 1" angular gravels 5.0 to 5.2'; wind blown 0 to 5.0'; (SM-SC).

SENTINEL BUTTE FORMATION - PALEOCENE

5.2-25.0 SANDSTONE: Tan & oxidized 5.2 to 7.0'; light gray 7.0 to 24.4'; tan & oxidized 24.4 to 25.0'; dry to moist; compact; silty sandstone with 20% nonplastic fines 5.2 to 15.0' (crumbles easily between fingers); fine grain, uncemented, near clean sandstone 15.0 to 24.4' (disintegrated by drill water); hard; cemented, fine grain sandstone 24.4 to 24.9'; lignitic clayshale 24.9 to 25.0'; occasional thin white caliche streaks 8.0 to 8.5'; pulverized to 2" core lengths.

25.0-27.6 LIGNITE: Soft & broken.

27.6-30.3 SHALE & SILTSTONE: Medium brown & oxidized with highly oxidized yellow-brown streaks 29.0 to 29.2 & 29.4 to 29.5'; moist; trims easily with knife; upper part is plastic shale grading to clayey siltstone with depth; oxidized with gypsum crystals 27.6 to 27.8'; core lengths 2 to 18".

30.3-44.8 SANDSTONE: Tan & oxidized 30.3 to 39.4'; light gray 39.4 to 44.8'; moist; uncemented; compact; pulverized; crushes easily between fingers; very fine grain (approaching silt); silty sandstone 30.3 to 33.3' with several silty shale laminations 32.6 to 33.3'; silty, fine grain sandstone 33.3 to 44.8' (silt content decreasing with depth); bedding not readily discernible; core lengths 3 to 18".

44.8-53.7 LIGNITE: Black & soft 44.8 to 48.0'; layered dark brown to black & hard 48.0 to 53.7'; broken to 48.0'; 1 to 6" core lengths 48.0 to 53.7'.

53.7-69.6 SHALE, SILTSTONE & SANDSTONE: Light to medium gray; moist; laminated to thin-bedded; siltstones & sandstones crumble easily between fingers; shales are moderately firm & cut easily with knife;

53.7-53.8 - silty shale with lignitic streaks.

53.8-57.7 - mostly silty sandstone with several 1 to 2" silty shale streaks; laminated silty shale, siltstone & sandstone 55.7 to 57.7'; ¼ to ½" marcasite

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

GEOLOGIC LOG OF DRILL HOLE

7-1337 (9-69) Bureau of Reclamation — SHEET 2 OF 3

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: North Dakota

HOLE NO.: DH 75-102 — LOCATION: 1930' E. & 2670' N. of SW. Corner Section 15, T. 144 N., R. 94 W. — GROUND ELEV.: Altimeter 2350± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 10/3/75 — FINISHED: 10/10/75 — TOTAL DEPTH: 208.7 — BEARING: --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 168.3' 11/4/75 (2181.7) — LOGGED BY: Taucher — LOG REVIEWED BY:

Notes on drilling conditions:

Hole at 132.8' 10/8/75. 6" Cs at 14.5'. W.L. at 61.7'. 2-3/4" wire line core 132.8 to 183.9'. Slight water loss 132.8 to 164.0'. Lost most drill water 164.0 to 183.9'. Using revert.

Hole at 183.9' 10/9/75. 6" Cs at 14.5'. W.L. at 163.2'. 2-3/4" wire line core 183.9 to 197.7'. Dropped core 183.9 to 190.0' in hole. This zone washed away during redrill. No drill water return.

Core recovery (%): 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 0, 100, 100, 100

Sample	From	To
#7	104.9	137.4
#8	137.4	161.6
#9	178.2	201.7

Elevation (feet)	Depth (feet)
2248.7	101.3
2245.1	104.9
2212.6	137.4
2188.4	161.6
2186.1	163.9
2171.8	178.2

Graphic log labels: E, F, G

Classification and physical condition:

nodules along bedding planes at 54.6 & 55.0'.

57.7-61.4 - laminated moderately plastic silty shale & plastic shale; several lignite inclusions 60.0 to 60.6'; 60° slickenside at 60.0'; 45° slickenside at 60.6'.

61.4-63.6 - alternating laminations of silty, very fine grain sandstone, siltstone & silty shale.

63.6-69.6 - mostly silty, very fine grain sandstone with siltstone & silty shale laminations 63.6 to 65.6 & 69.0 to 69.6'.

69.6-85.6 SHALE: Silty; medium gray; moist; firm; trims by knife with some difficulty; occasional minus ½" marcasite nodule; plastic to moderately plastic; air slacks in places; bedding not readily discernible; lignite with associated slickensides 70.4 to 70.7, 70.9 to 71.0, 71.3 to 71.4, 71.6 to 71.8 & 82.9 to 83.6'; lignitic shale 83.6 to 83.9'; ½" 60° lignite filled fracture at 73.4'; core lengths 6 to 18".

85.6-88.6 SANDY SILTSTONE: Light gray; moist; crumbles easily between fingers; contains streaks of silty, very fine grain sandstone; bedding not readily discernible; core lengths up to 6".

88.6-101.3 SANDSTONE: Light gray; moist; compact; fine grain; uncemented; crumbles easily between fingers; generally free of fines except silty sandstone 90.0 to 93.6'; pulverized to 18" core lengths.

101.3-104.9 LIGNITE: Black; 3/8" marcasite filled 45° fracture at 104.5'.

104.9-137.4 SHALE: Medium gray; moist; generally firm; trims by knife with some difficulty; plastic with moderately plastic silty shale streaks; lignite along 25° fracture 110.4 to 110.6'; 2" irregular lignite healed 50° fracture at 114.8'; 60° fracture at 115.7'; ½" lignite at 117.8'; 70° joint at 119.3 to 120.0'; lignite 122.5 to 122.6'; 45° slickenside at 123.9'; ½" lignite 125.4 to 125.9'; lignite 126.2 to 126.4'; ½" lignite healed 65° joint & ½" lignite healed 15° joint (?) at 127.8 & 127.9'; soft siltstone 131.3 to 131.6'; lignite 132.0 to 132.1'; 70° fracture at 132.3'; black carbonaceous shale with lignite streaks 136.6 to 137.1'; core lengths 3 to 18".

137.4-161.6 SILTY SANDSTONE WITH SANDY SILTSTONE & SILTY SHALE: Light gray; moist; uncemented; mostly silty fine grain sandstone with about 25% sandy siltstone;

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

GEOLOGIC LOG OF DRILL HOLE

7-1337 (9-69) Bureau of Reclamation — SHEET 3 OF 3

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: North Dakota

HOLE NO.: DH 75-102 — LOCATION: 1930' E. & 2670' N. of SW. Corner Section 15, T. 144 N., R. 94 W. — GROUND ELEV.: Altimeter 2350± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 10/3/75 — FINISHED: 10/10/75 — TOTAL DEPTH: 208.7 — BEARING: --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 168.3' 11/4/75 (2181.7) — LOGGED BY: Taucher — LOG REVIEWED BY:

Notes on drilling conditions:

Hole at 197.7' 10/10/75. 6" Cs at 14.5'. W.L. at 163.8'. 2-3/4" wire line core 197.7 to 208.7'. No drill water return. Lost drill water at rate of 1000 gallons in 25 minutes. Hole staying open. Did not use revert. Pulled 6" Cs. Hole completed. Moved rig to DH 75-104.

5 pound Lignite samples taken at the following intervals:
25.0 to 27.6'
45.2 to 47.7
50.8 to 53.6
102.3 to 104.4
164.3 to 166.7
170.0 to 172.4
175.8 to 178.2

11/4/75 W.L. 168.3' below ground surface. Gravel packed around plastic pipe (pipe installed by U.N.D.) Cleaned up drill site.

Core recovery (%): 100, 100

Sample	From	To
#10	201.7	208.7

Elevation (feet)	Depth (feet)
2148.3	201.7
2141.3	208.7

Classification and physical condition:

crushes easily between fingers; moderately calcareous; generally laminated; soft silty shale streaks 137.4 to 142.5'; becoming more silty & clayey below 160.6'; ¼ to 1" marcasite nodules 160.1 & 160.6'; pulverized with some core lengths up to 12".

161.6-163.9 SHALE: Medium gray; moist; plastic; soft to firm; trims by knife with some difficulty; bedding not readily discernible; 45° joint at 163.0'; lignitic 163.8 to 163.9'; core lengths 3 to 12".

163.9-178.2 LIGNITE: Black to dark brown; wet; hard; broken along bedding planes on 1 to 8" centers.

178.2-201.7 SHALE WITH SILTSTONE: Medium to dark gray 178.2 to 179.6' with black lignite 179.0 to 179.2'; light to medium gray 179.6 to 201.7'; moist; soft (cuts easily with knife) 178.2 to 179.2'; firm (difficult trimming with knife) 179.2 to 201.7'; moderately plastic to plastic shale 178.2 to 198.0'; laminated, moderately plastic silty shale 198.0 to 201.7' with laminated low plasticity clayey siltstone 199.0 to 200.2'; air slacks 178.7 to 198.0'; minor HCl reaction in zones; 40° slickenside at 194.9'; 6 to 18" core lengths.

201.7-208.7 SILTY SANDSTONE: Light gray; moist; laminated to thin-bedded, uncemented, very silty, fine grain sandstone 201.7 to 202.4 & 203.2 to 208.7' (crumbles easily between fingers); hard, calcareous cemented, silty, very fine grain sandstone 202.4 to 203.2' (scratches with knife); core lengths 8 to 14".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

GEOLOGIC LOG OF DH 75-102

GEOLOGY: S. TAUCHER — SUBMITTED:
DRAWN: — RECOMMENDED:
CHECKED: — APPROVED:

BILLINGS, MONT. — MAY 1976 — 1305-600-84

7-1337 (9-60)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: North Dakota
HOLE NO. DH 75-103 — LOCATION: 670' N. of SW Corner, Section 14, T. 144 N., R. 94 W. — GROUND ELEV. (Hand Level) 2339± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 11/6/75 — FINISHED: 11/13/75 — TOTAL DEPTH: 202.8 — BEARING: —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 30.4' 11/21/75 (2308.6) — LOGGED BY: Taucher — LOG REVIEWED BY:

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole started 11/6/75. Nx drive samples 0 to 10.0'.

Hole at 10.0' 11/7/75. Hole dry. Nx drive samples 10.0 to 23.0'. Set 6" Cs to 20.0'. Cleaned out hole to 23.0' with drag bit. 2-3/4" wire line core 23.0 to 30.0' silty sandstone 27.5 to 30.0'. Washed away during drilling. No drill water loss.

Hole at 30.0' 11/10/75. 6" Cs at 20.0'. W.L. at 15.1'. 2-3/4" wire line core 30.0 to 73.5'. Silty sand 30.0 to 33.5' wash-away during drilling. No drill water loss. Using revert.

Hole at 73.5' 11/11/75. 6" Cs at 20.0'. W.L. at 20.2'. 2-3/4" wire line core 73.5 to 153.5'. Hole squeezing. Reamed hole to 103.5' with 5-1/8" drag bit. Losing 5 gallons of water per minute to 150.4'. Losing 25 gallons of water per minute below 150.4'. Using revert.

Soils analysis samples (depth, feet):

Sample	From	To
#1	0	5.0
#2	5.0	21.7
#3	25.0	47.7
#4	47.7	55.4
#5	65.2	75.9
#6	75.9	87.0
#7	87.0	106.4

Elevation / depth (feet): 2334.0 / 5.0; 2317.3 / 21.7; 2315.3 / 23.7; 2314.0 / 25.0; 2291.3 / 47.7; 2283.6 / 55.4; 2273.8 / 65.2; 2263.1 / 75.9; 2252.0 / 87.0

Classification and physical condition:

0-5.0 SILTY SAND: Dark gray & organic with roots 0 to 1.6'; tan 1.6 to 5.0'; dry; soft; calcareous 4.0 to 5.0'; approximately 70% fine, uniform sand & 30% non to slight plasticity fines; wind blown (SM).

SENTINEL BUTTE FORMATION - PALEOCENE

5.0-21.7 SANDSTONE: Tan; dry to damp; oxidized; uncemented; pulverized by drilling; fine grain; 10 to 15% silt; crumbles between fingers; maximum core length 1".

21.7-23.7 SILTY SHALE: Gray-brown; moist; soft; cuts very easily with knife; oxidized; laminated; several thin lignite streaks 23.4 to 23.7'; core lengths ½ to 2".

23.7-25.0 LIGNITE: Black; soft; broken.

25.0-47.7 SANDSTONE & SILTY SANDSTONE: Tan & oxidized 25.0 to 41.6'; light gray & unoxidized 41.6 to 47.7'; moist; uncemented; fine grain; crumbles easily between fingers; bedding not readily discernible; core lengths 1 to 18".
25.0-27.5 - Very silty & very fine grain sandstone (approaching silt); uncemented siltstone 25.0 to 25.6 & 26.0 to 26.6'; carbonaceous 25.0 to 25.3'.
27.5-33.5 - Sample washed away. Driller reported silty sandstone.
33.5-47.7 - Fine grain sandstone with about 15% silt; 1" lignite inclusion at 47.5'.

47.7-55.4 SILTY SHALE: Light to medium gray; moist; moderately firm; trims easily with knife; bedding not readily discernible; hard clayatone concretion at 50.6 to 50.7, 51.4 to 51.5 & 54.1 to 54.3'; ½" marcasite nodules along a bedding plane at 48.5'; dark gray & carbonaceous with 1/8 to ½" marcasite or pyrite nodules along a bedding plane at 55.4'; air slacks; core lengths 6 to 18".

55.4-65.2 LIGNITE: Banded black to dark brown; hard; moist; 1 to 8" core lengths 55.4 to 64.2'; soft & broken 64.2 to 65.2'.

65.2-75.9 SILTY SHALE WITH SILTY SANDSTONE: Shale is medium gray, very silty & moderately plastic (trims easily with knife); sandstone is light gray, silty & fine grain (crumbles easily between fingers) thin-bedded to laminated in zones; core lengths 2 to 18"; silty sandstone 67.0 to 67.2, 67.4 to 67.5, 67.6 to 67.7, 68.1 to 68.1 & 68.4 to 68.7'; remainin[g]

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: N. Dakota — SHEET 1 OF 3 — HOLE NO. DH 75-103

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: North Dakota
HOLE NO. DH 75-103 — LOCATION: 670' N. of SW Corner, Section 14, T. 144 N., R. 94 W. — GROUND ELEV. (Hand Level) 2339± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 11/6/75 — FINISHED: 11/13/75 — TOTAL DEPTH: 202.8 — BEARING: —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 30.4' 11/21/75 (2308.6) — LOGGED BY: Taucher — LOG REVIEWED BY:

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole at 153.5' 11/12/75. 6" Cs at 20.0'. W.L. at 42.4'. 2-3/4" wire line core 153.5 to 190.4'. Losing 25 gallons of water per minute. Lost core 159.6 to 163.5'.

Hole at 190.4' 11/13/75. 6" Cs at 20.0'. W.L. at 87.3'. 2-3/4" wire line core 190.4 to 202.8'. Washed away core 190.4 to 193.5'. Losing 25 gallons of water per minute. Pulled 6" Cs & moved rig to DH 75-105. Hole completed.

Soils analysis samples (depth, feet):

Sample	From	To
#8	108.2	123.7
#9	123.7	150.4
#10	154.7	169.6
#11	185.1	202.8

Elevation / depth (feet): 2232.6 / 106.4; 2230.8 / 108.2; 2215.3 / 123.7; 2188.6 / 150.4; 2184.3 / 154.7; 2169.4 / 169.6; 2153.9 / 185.1

Classification and physical condition:

material is silty shale; ½" marcasite nodules along bedding planes at 70.9 & 74.8'; ½" lignite filled, 60° fracture at 68.9'; horizontal slickenside at 65.9'.

75.9-87.0 SILTY SANDSTONE: Light gray; moist; uncemented; crumbles easily between fingers; fine grain; scattered medium gray carbonaceous laminations 75.9 to 77.5'; ½" marcasite nodules along a bedding plane at 87.0'; core lengths 3 to 18".

87.0-106.4 SILTY SHALE WITH SILTY SANDSTONE: Medium gray; moist; moderately firm; cuts easily with knife; moderately plastic; thin-bedded to laminated; hard claystone concretions 87.0 to 87.1'; hard lignite 87.6 to 88.1'; dark gray, carbonaceous shale 88.1 to 88.4'; laminated silty shale & silty sandstone 92.6 to 92.9, 94.2 to 94.8, 95.1 to 95.4, 95.8 to 96.5 & 97.0 to 97.5'; 80° strike-slip slickenside at 88.4'; 40° joint at 91.6'; 70° parallel joints at 96.8 & 97.0'; core lengths 8 to 24".

106.4-108.2 LIGNITE: Banded black & dark brown; hard; 80° hairline fracture 106.1 to 107.2'; core lengths 2 to 6".

108.2-123.7 SILTY SHALE WITH SILTSTONE: Shale is medium gray, moderately firm & moderately plastic (cuts easily with knife); siltstone is clayey to sandy, uncemented & light gray (crumbles easily between fingers); moist; slight HCl reaction; core lengths 6 to 24".
108.2-110.3 - Silty shale; bedding not readily discernible.
110.3-119.8 - Alternating laminations of silty shale, clayey siltstone & sandy siltstone.
119.8-122.6 - Silty shale; bedding not readily discernible.
122.6-123.7 - Alternating laminations of silty shale, clayey siltstone & sandy siltstone.

123.7-150.4 SANDSTONE WITH SILTY SANDSTONE: Light gray; moist; uncemented; crumbles easily between fingers; slightly calcareous; core lengths 2 to 24".
123.7-128.0 - Laminated silty, very fine grain sandstone.
128.0-150.4 - Fine grain sandstone; bedding not readily discernible; silty sandstone 144.6 to 145.1'; 80° joint 136.5 to 137.5'; begins to wash away during drilling.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: N. Dakota — SHEET 2 OF 3 — HOLE NO. DH 75-103

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: North Dakota
HOLE NO. DH 75-103 — LOCATION: 670' N. of SW Corner, Section 14, T. 144 N., R. 94 W. — GROUND ELEV. (Hand Level) 2339± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 11/6/75 — FINISHED: 11/13/75 — TOTAL DEPTH: 202.8 — BEARING: —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 30.4' 11/21/75 (2308.6) — LOGGED BY: Taucher — LOG REVIEWED BY:

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

5 pound Lignite samples taken at the following intervals
56.5 to 59.0'
61.0 to 63.5
151.2 to 153.5
171.0 to 173.5
176.2 to 178.5
180.6 to 183.5

11/21/75. W.L. at 30.4'. Backfilled hole with pea gravel.

Elevation / depth (feet): 2136.2 / 202.8

Classification and physical condition:

150.4-154.7 LIGNITE: Black; hard; broken; moist to wet.

154.7-169.6 SHALE, CARBONACEOUS SHALE & LIGNITE: Medium to dark gray; moist; firm; cuts by knife with some difficulty; plastic; air slacks; generally thin-bedded; lignitic 154.7 to 154.8'; 1" lignite inclusion at 155.7'; lignite with shale streaks 155.9 to 156.2'; ½" lignite at 156.3'; dark gray lignitic shale 156.3 to 156.7'; 1" lignite at 157.3'; dark gray lignitic shale 157.8 to 158.8'; with 1" lignite at 158.5'; dark gray lignitic shale 159.1 to 159.4'; lignite 159.4 to 159.6'; medium to dark gray plastic shale with 1/8 to ½" lignite streaks on 1 to 12" centers 159.6 to 169.4'; black lignitic shale 169.4 to 169.6'; 45° slickenside at 157.8 & 159.1'; 25° slickenside at 168.5'; core lengths 2 to 12".

169.6-185.1 LIGNITE: Banded black to dark brown; wet; hard; broken on 1 to 8" centers along bedding planes.

185.1-202.8 SHALE WITH SILTSTONE: Medium gray; moist; shales are plastic, firm & trim by knife with some difficulty; air slacks; core lengths 6 to 18".
185.1-185.8 - Light to dark gray, carbonaceous, fine grain silty sandstone; crumbles easily between fingers.
185.8-189.8 - Shale; becoming dark gray & carbonaceous 189.0 to 189.8'.
189.8-190.4 - Broken, hard lignite.
190.4-193.5 - Core washed away; driller reported clayey siltstone.
193.5-194.8 - Shale.
194.8-195.8 - Laminated medium gray shale & light gray clayey siltstone.
195.8-202.8 - Medium to dark gray plastic, carbonaceous shale with lignite 199.5 to 199.8'; cut by numerous irregular 10 to 45° slickensides on 1 to 4" centers.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: N. Dakota — SHEET 3 OF 3 — HOLE NO. DH 75-103

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

GEOLOGIC LOG OF DH 75-103

GEOLOGY: G. TAUCHER — SUBMITTED
DRAWN — RECOMMENDED
CHECKED — APPROVED
BILLINGS, MONT. — MAY 1976 — 1305-600-85

7-1337 (9-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT EMRIA No. 9 — STATE North Dakota
HOLE NO. DH 75-104 — LOCATION 1070' S. of NE Corner, Section 15, T. 144 N., R. 94 W. — GROUND ELEV. Altimeter 2281± — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 10/14/75 — FINISHED 10/20/75 — TOTAL DEPTH 133.5 — BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 46.2' 11/4/75 (2234.8) — LOGGED BY Taucher — LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started 10/14/75. Nx drive samples 0 to 15.0'. Stopped work to prevent road damage due to muddy field conditions.

Hole at 15.0' 10/15/75. Nx drive samples & core 15.0 to 31.1'. Set 6" Cs to 5.0'. 2-3/4" wire line core 31.1 to 35.5'. Cleaned out hole with drag bit to 35.5'. Nx diamond core (granite boulder) 35.5 to 36.8'. Shot rock (2 sticks of powder & 1 cap) 35.5 to 36.8'. Cleaned out hole with 4" drag bit to 36.8'. Very little water loss. Hole dry at start of shift.

Hole at 36.8' 10/16/75. 6" Cs at 5.0'. W.L. at 33.8'. Nx drive samples 36.8 to 44.7 & 46.3 to 47.0'. Drag bit (too hard to drive sample) 44.7 to 46.3'. 2-3/4" wire line core 47.0 to 73.4'. Using revert.

Hole at 73.4' 10/17/75. 6" Cs at 5.0'. W.L. at 12.2'. 2-3/4" wire line core 73.4 to 103.6'. Little or no water loss. Using revert.

CORE RECOVERY (%): 100, 63, 70, 100, 62, 92, 30, 100, 100, 100, 100, 0, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100

SOILS ANALYSIS SAMPLE — DEPTH (FEET)

Sample	From	To
#1	0	16.5
#2	16.5	31.1
#3	36.8	46.5
#4	50.0	80.8

ELEVATION (FEET) / DEPTH (FEET)

Elevation	Depth
2264.5	16.5
2259.5	21.5
2249.9	31.1
2245.5	35.5
2244.2	36.8
2239.5	41.5
2234.5	46.5
2231.0	
2200.2	80.8
2181.6	99.4

E

F

CLASSIFICATION AND PHYSICAL CONDITION

0-16.5 SILTY CLAY: Brown & slightly organic 0 to 1.0'; tan & oxidized 1.0 to 16.5'; moist; soft; approximately 35% fine, uniform sand & 65% low to medium plasticity fines; active HCl reaction 0 to 2.5'; slight HCl reaction 2.5 to 16.5'; scattered vertical root holes to 10'; few coarse sand grains & lignite fragments below 10'; upper 10' appears to be wind deposited; lower 6.5' appears to be deposited both by wind & water (reworked glacial till); moderately plastic 0 to 2.5' (CL); slightly to moderately plastic 2.5 to 16.5' (CL to ML-CL).

16.5-21.5 SILTY CLAY TO CLAY: Tan; oxidized; moist; soft; approximately 40% mostly fine sand & 60% low to medium plasticity fines; laminated plastic clay 16.5 to 18.0' (lacustrine?); scattered large sand grains & lignite fragments 18.0 to 21.5' (could be partly reworked glacial till); very soft, wet & mushy 18.0 to 19.3' (CL).

21.5-31.1 SANDY CLAY: Tan with black lignite fragments; oxidized; moist; moderately firm (cuts easily with knife); approximately 35% fine to coarse, hard, subrounded to subangular sand with few fine gravels & 65% medium to high plasticity fines; numerous lignite fragments making core appear mottled black & tan 27.1 to 31.1'; laminated silt, sand & clay 30.5 to 31.1'; glacial till 21.5 to 30.5'; lacustrine deposits 30.5 to 31.1' (CL).

31.1-35.5 LIMESTONE BOULDER: Broken in 1 to 3" core lengths; very hard.

35.5-36.8 GRANITE BOULDER: Very hard; 6 to 12" core lengths.

36.8-41.5 SILTY SAND: Brown; moist; oxidized; approximately 80% mostly medium to coarse, hard, subrounded sand, 5% hard, subrounded gravel & 15% very low plasticity fines; slight cohesion; active HCl reaction; terrace or channel deposits (SM to SM-SC).

41.5-46.5 SILTY SAND & GRAVEL: Brown; moist; oxidized; approximately 15% low plasticity fines, 35% hard subrounded gravel (maximum size 3/4") & 50% mostly medium to coarse, hard, subrounded sand; few lignite & shale fragments; active HCl reaction; terrace or channel deposits (SM to SM-SC).

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . O = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT EMRIA No. 9 — STATE N. Dakota — SHEET 1 OF 3 — HOLE NO. DH 75-104

7-1337 (9-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT EMRIA No. 9 — STATE North Dakota
HOLE NO. DH 75-104 — LOCATION 1070' S. of NE Corner, Section 15, T. 144 N., R. 94 W. — GROUND ELEV. Altimeter 2281± — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 10/14/75 — FINISHED 10/20/75 — TOTAL DEPTH 133.5 — BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 46.2' 11/4/75 (2234.8) — LOGGED BY Taucher — LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole at 103.6' 10/20/75. 6" Cs at 5.0'. W.L. at 19.0'. 2-3/4" wire line core 103.6 to 133.5'. Little or no drill water loss. Using revert. Hole completed at 133.5'.

5 pound Lignite samples taken at the following intervals:
46.8 to 48.9'
81.4 to 83.7
86.3 to 89.4
91.4 to 93.9
96.5 to 99.0

10/21/75 W.L. 19.3' below ground surface.

11/4/75 W.L. 46.2' below ground surface. Backfilled hole with pea gravel. Cleaned up drill site.

CORE RECOVERY (%): 100, 100, 100, 100, 100, 43, 100, 100

SOILS ANALYSIS SAMPLE — DEPTH (FEET)

Sample	From	To
#5	99.4	114.0
#6	114.0	118.4
#7	118.4	123.5
#8	123.5	133.5

ELEVATION (FEET) / DEPTH (FEET)

Elevation	Depth
2167.0	114.0
2162.6	118.4
2157.5	123.5
2147.5	133.5

G

CLASSIFICATION AND PHYSICAL CONDITION

SENTINEL BUTTE FORMATION - PALEOCENE

46.5-50.0 LIGNITE: Black; moderately soft to firm; pulverized to 3" core lengths.

50.0-80.8 SILTY SHALE & CLAYEY SILTSTONE: Light gray; moist; firm; trims by knife with some difficulty; core lengths 6 to 14".
50.0-54.2 - Moderately plastic silty shale; bedding not readily discernible; several 1/8" lignite streaks 53.2 to 54.2'.
54.2-56.3 - Slightly plastic clayey siltstone; bedding not discernible.
56.3-60.0 - Moderately plastic silty shale; bedding not readily discernible; clayey siltstone 59.0 to 60.0'; bottom contact is 70° irregular slickenside (fault?); ½" lignite at 56.9'; 3/4" lignite at 57.2'; 1½" lignite at 58.2'.
60.0-60.8 - Black, hard lignite; top contact is irregular 70° slickenside (fault?); bottom contact is 40° slickenside (fault?).
60.8-72.6 - Alternating low plasticity clayey siltstone & moderately plastic silty shale; laminated in zones; lignitic 62.3 to 62.5'; 3 - 1/8 to 1/4" lignite streaks 64.2 to 65.2'; lignitic shale 67.0 to 67.3'; 4 - 1/8 to 1/4" lignite streaks 68.2 to 68.5'; dark gray lignitic shale with 1 to 3" lignite streaks 68.4 to 69.4'; lignite 71.2 to 72.1'; 1" lignite at 77.8'; medium to dark gray lignitic shale with numerous ½ to 2" lignite streaks 77.8 to 79.8'; lignite 79.8 to 80.1'.

80.8-99.4 LIGNITE: Black to dark gray; moderately hard to hard; breaks along bedding; 1 to 3" core lengths.

99.4-114.0 SILTY SHALE: Medium gray; moist; firm; trims by knife with difficulty; scattered 1/8 to ½" marcasite nodules generally along bedding planes; moderately plastic to plastic; bedding not readily discernible; becoming more silty below 112.5'; 50° slickensides at 104.5 & 106.6'; lignite 109.0 to 109.4'; core lengths 3 to 24".

114.0-118.4 SILTY SANDSTONE TO SANDY SILTSTONE: Light gray; moist; clayey (low to medium plasticity); crushes between fingers with difficulty; varies from silty, fine grain sandstone to sandy siltstone; thin-bedded; core lengths 12 to 36".

118.4-123.5 SILTY SHALE TO CLAYEY SILTSTONE: Laminated light to medium gray; moist;

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . O = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT EMRIA No. 9 — STATE N. Dakota — SHEET 2 OF 3 — HOLE NO. DH 75-104

7-1337 (9-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT EMRIA No. 9 — STATE North Dakota
HOLE NO. DH 75-104 — LOCATION 1070' S. of NE Corner, Section 15, T. 144 N., R. 94 W. — GROUND ELEV. Altimeter 2281± — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 10/14/75 — FINISHED 10/20/75 — TOTAL DEPTH 133.5 — BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 46.2' 11/4/75 (2234.8) — LOGGED BY Taucher — LOG REVIEWED BY

CLASSIFICATION AND PHYSICAL CONDITION

firm; trims by knife with some difficulty; alternating medium plastic silty shale & low plasticity clayey siltstone; hard; cemented claystone concretion 120.4 to 120.8'; silty fine grain sandstone 120.8 to 121.2'; scattered 1/8 to ½" marcasite nodules generally along bedding planes; 3 to 36" core lengths.

123.5-133.5 SANDSTONE: Alternating laminations of light gray sandstone & medium gray clayey siltstone 123.5 to 125.5'; near clean, fine grain, uncemented sandstone 125.5 to 133.5'; moist; crumbles easily between fingers; several ½" marcasite nodules 123.5 to 125.5'; core lengths 8 to 24".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole . . . O = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT EMRIA No. 9 — STATE N. Dakota — SHEET 3 OF 3 — HOLE NO. DH 75-104

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

GEOLOGIC LOG OF DH 75-104

GEOLOGY G. TAUCHER — SUBMITTED
DRAWN — RECOMMENDED
CHECKED — APPROVED
BILLINGS, MONT. — MAY 1976 — 1305-600-86

7-1337 (9-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: North Dakota
HOLE NO. DH 75-105 — LOCATION: 2700' N. & 1050' W. of SE Corner, Section 14, T. 144 N., R. 94 W. — GROUND ELEV.: Altimeter 2273± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 11/13/75 — FINISHED: 11/18/75 — TOTAL DEPTH: 133.6 — BEARING: --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 25.0' 12/8/75 (2248.0) — LOGGED BY: Taucher — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started 11/13/75. Nx drive samples 0 to 5.0'.

Hole at 5.0' 11/14/75. Hole dry. Nx drive samples 5.0 to 20.0'. Nx rotation 20.0 to 31.8'. Set 6" Cs to 15.0'.

Hole at 31.8' 11/17/75. 6" Cs at 15.0'. W.L. at 10.8'. 2-3/4" wire line core 31.8 to 62.0'. Using revert. Little or no water loss.

Hole at 62.0' 11/18/75. 6" Cs at 15.0'. W.L. at 20.6'. 2-3/4" wire line core 62.0 to 133.6'. Using revert. No drill water loss. Hole completed at 133.6'.

11/21/75 - W.L. at 17.6' (2255.4)

12/8/75 - W.L. at 25.0' (2248.0). Backfilled hole with pea gravel.

CORE RECOVERY (%): 100, 100, 100, 92, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100

SOILS ANALYSIS SAMPLE — DEPTH (FEET)

Sample	From	To
#1	0	12.4
#2	12.4	31.8
#3	33.8	54.9
#4	56.8	70.1
#5	77.3	80.9

SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE / LIMITED SUITABILITY / UNSUITABLE

Elevation (feet)	Depth (feet)
2260.6	12.4
2241.2	31.8
2239.2	33.8
2218.1	54.9
2216.2	56.8
2202.9	70.1
2196.5	76.5
2195.7	77.3
2192.1	80.9

D E F

CLASSIFICATION AND PHYSICAL CONDITION

0-12.4 SILTY SAND: Dark gray & organic 0 to 1.6'; tan 1.6 to 12.4'; dry to damp; approximately 85% fine, uniform sand & 15% nonplastic fines; few pebbles at 5.0'; mostly wind deposited (SM); sandy clay (glacial till - CL) 9.0 to 9.5'.

12.4-31.8 SANDY CLAY: Brown; becoming gray-brown with depth; oxidized; moist; soft; approximately 60% medium plasticity fines, 35% mostly fine sand with occasional coarse sand grain & 5% fine to medium gravel (maximum size 1½"); very slight HCl reaction; calcareous 31.2 to 31.8'; glacial till (CL).

SENTINEL BUTTE FORMATION - PALEOCENE

31.8-33.8 SILTY SANDSTONE: Gray-brown 31.8 to 33.8'; brown 33.0 to 33.8'; moist; oxidized; silty, very fine grain sand; firm & calcareous (crushes between fingers with difficulty) 31.8 to 33.0'; uncemented & noncalcareous (crushes easily between fingers) 33.0 to 33.8'; 70° oxidized joint 33.0 to 33.8'; 1 to 6" core lengths.

33.8-54.9 CLAYEY SILTSTONE & SILTY SHALE: Medium gray; moist; generally thin-bedded to laminated; siltstones are low plasticity & crumble between fingers; shales are moderately plastic to plastic & trim easily with knife; very slight HCl reaction.
33.8-38.8 - Siltstone with shale laminations.
38.8-39.0 - Hard, claystone concretion.
39.0-43.0 - Shale with claystone concretion 42.7 to 42.9' & siltstone 39.6 to 39.8, 40.2 to 40.4 & 41.0 to 41.3'.
43.0-45.0 - Siltstone.
45.0-46.0 - Shale.
46.0-47.8 - Siltstone.
47.8-54.9 - Shale; 60° slickenside at 51.6'; core lengths 3 to 18".

54.9-56.8 LIGNITE: Black; moist; soft; broken.

56.8-70.1 SHALE WITH SILTY SANDSTONE & CLAYEY SILTSTONE: Shales are medium gray; plastic, moderately firm & trim by knife with some difficulty; silty sandstones are light gray, fine grain, uncemented & crumble between fingers; clayey siltstones are light to medium gray, slightly plastic & crumble between fingers with some difficulty; moist; slight acid reaction; core lengths 3 to 12".
56.8-60.0 - Shale, bedding not discernible.
60.0-61.2 - Silty sandstone with clayey siltstone laminations.
61.2-66.0 - Shale with occasional

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: N. Dakota — SHEET 1 OF 2 — HOLE NO. DH 75-105

7-1337 (9-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: North Dakota
HOLE NO. DH 75-105 — LOCATION: 2700' N. & 1050' W. of SE Corner, Section 14, T. 144 N., R. 94 W. — GROUND ELEV.: Altimeter 2273± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 11/13/75 — FINISHED: 11/18/75 — TOTAL DEPTH: 133.6 — BEARING: --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 25.0 12/8/75 (2248.0) — LOGGED BY: Taucher — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

5 pound Lignite samples taken at the following intervals:
71.2 to 74.2'
81.3 to 84.3
87.3 to 90.0
93.6 to 96.2
99.3 to 102.0

CORE RECOVERY (%): 100, 100, 100, 100

SOILS ANALYSIS SAMPLE — DEPTH (FEET)

Sample	From	To
#6	103.5	133.6

Elevation (feet)	Depth (feet)
2170.5	102.5
2169.5	103.5
2139.4	133.6

G

CLASSIFICATION AND PHYSICAL CONDITION

laminated clayey siltstone zones up to 3" thick.
66.0-69.1 - Alternating laminations of shale, clayey siltstone & sandstone.
69.1-70.1 - Shale, air slacks.

70.1-76.5 LIGNITE: Black; moist to wet; moderately soft; broken along bedding planes on 1/8 to 2" centers.

76.5-77.3 LIGNITIC SHALE: Black; moist; firm; difficult trimming by knife; plastic; about 40% of material is lignite; cut by numerous 0 to 25° slickensides; air slacks; broken in 1 to 3" core lengths.

77.3-80.9 SHALE: Medium gray; moist; firm; trims by knife with some difficulty; plastic; air slacks; core lengths 6 to 18".

80.9-102.5 LIGNITE: Banded black to dark brown; wet; hard; badly broken 82.6 to 84.0 & 93.6 to 102.5'; remaining core is in 1 to 6" lengths; occasional 80 to 90° hair-line fractures.

102.5-103.5 SILTSTONE: Dark gray; moist; crumbles between fingers with difficulty; some fine sand & clay (low plasticity); highly carbonaceous 102.5 to 102.8'; moderately carbonaceous 102.8 to 103.5'; core lengths 2 to 6".

103.5-133.6 SHALE WITH SOME LIGNITE: Medium to dark gray; moist; firm; trims by knife with some difficulty; moderately plastic to plastic; varies from shale to silty shale; air slacks; 60° joint at 130.6'; core lengths 6 to 18".
103.5-107.1 - Plastic, slightly carbonaceous dark gray shale.
107.1-107.8 - Black, hard lignite.
107.8-119.2 - Plastic, medium to dark gray shale with dark gray carbonaceous zones 111.0 to 111.5 & 114.7 to 115.7'.
119.2-121.3 - Alternating laminations of dark gray plastic shale & medium gray clayey siltstone.
121.3-121.6 - Hard, cemented claystone concretion.
121.6-133.6 - Medium to dark gray plastic shale; 3/4" lignite at 127.2'; 1" lignite at 128.2'; lignite 130.6 to 130.8'; 50° joint at 123.9'; 60° joint at 131.0'.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA N. 9 — STATE: N. Dakota — SHEET 2 OF 2 — HOLE NO. DH 75-105

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

GEOLOGIC LOG OF DH 75-105

GEOLOGY: G. TAUCHER — SUBMITTED:
DRAWN: — RECOMMENDED:
CHECKED: — APPROVED:
BILLINGS, MONT. — MAY 1976 — 1305-600-87

7-1337 (9-69) Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: North Dakota
HOLE NO. DH 75-106 — LOCATION: 2440' W. of SE Corner, Section 11, T. 144 N., R. 94 W. — GROUND ELEV: Altimeter 2344± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 10/21/75 — FINISHED: 11/4/75 — TOTAL DEPTH: 180.5 — BEARING: —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 67.1' 11/4/75 (2276.9') — LOGGED BY: Taucher — LOG REVIEWED BY:

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole started 10/21/75. Nx drive samples 0 to 15.0'. Set 6" Cs to 14.5'.

Hole at 15.0' 10/22/75. 6" Cs at 14.5'. W.L. at ground surface. 2-3/4" wire line core 15.0 to 63.6'. Washed away sample 16.6 to 22.3'. Losing 14 gallons of water per minute 16.6 to 22.3'. Advanced 6" Cs to 24.5'. Using revert.

Hole at 63.6' 10/23/75. 6" Cs at 24.5'. W.L. at 9.0'. 2-3/4" wire line core 63.6 to 133.5'. No drill water loss.

Soils analysis sample, depth (feet):

Sample	From	To
#1	2.0	22.3
#2	22.7	34.6
#3	34.6	44.9
#4	57.3	75.7
#5	78.2	81.3
#6	82.2	98.3

Elevation / Depth (feet):

Elevation	Depth
2242.0	2.0
2321.7	22.3
2321.3	22.7
2309.4	34.6
2299.1	44.9
2288.7	55.3
2286.7	57.3
2268.3	75.7
2268.1	75.9
2267.4	76.6
2265.8	78.2
2262.7	81.3
2261.8	82.2
2245.7	98.3

Classification and physical condition:

0-2.0 SILTY SAND: Brown & slightly organic with roots 0 to 1.0'; tan & oxidized 1.0 to 2.0'; soft; approximately 35% nonplastic fines; approximately 65% fine, uniform sand; probably wind deposited (SM).

SENTINEL BUTTE FORMATION - PALEOCENE

2.0-22.3 SANDSTONE: Tan & oxidized 2.0 to 9.0'; light gray 9.0 to 13.8'; highly oxidized, yellow-brown 13.8 to 16.0'; dark gray-brown, plastic, carbonaceous shale 16.0 to 16.6'; driller reported washing away brown sandstone 16.6 to 22.3'; damp to moist; fine grain; silty; crumbles easily between fingers; uncemented; bedding not readily discernible; pulverized.

22.3-22.7 LIGNITE: Black; hard; broken.

22.7-34.6 CLAYEY SILTSTONE: Gray-brown & oxidized 22.7 to 25.5'; medium gray & unoxidized 25.5 to 34.6'; moist; moderately firm but trims easily with knife; crumbles between fingers with difficulty; thin-bedded with clay & sand laminations 32.6 to 34.6'; scattered marcasite inclusions up to ½" in size mostly along bedding planes; low to medium plasticity; ¼" lignite stringers at 23.7 & 24.6'; 3/4" lignite at 27.7'; 60° slickenside at 23.0'; core lengths 2 to 12".

34.6-44.9 SILTY SANDSTONE: Light gray; moist; uncemented; crumbles easily between fingers; fine grain; silty; laminated in places; 70° joint at 35.4'; core lengths 6 to 12".

44.9-55.3 LIGNITE: Black to dark brown; hard; moist; broken along bedding planes on 1 to 4" centers.

55.3-57.3 SHALE: Medium gray; moist; firm; trims by knife with difficulty; plastic; thin-bedded to laminated; minute 1/8" lignite streaks on ½ to 2" centers; lignite 57.0 to 57.1'; 45° slickenside at 55.3'; ½" marcasite or pyrite nodules along bedding plane at 57.2'; core lengths 6 to 8".

57.3-75.7 SANDSTONE: Light gray; moist; some silt; fine grain; uncemented; crumbles easily between fingers; laminated sandstone, siltstone & shale 75.0 to 75.6'; hard claystone concretion with numerous small pyrite crystals 75.6 to 75.7'; core lengths 6 to 18".

75.7-75.9 LIGNITE: Soft; broken.

75.9-76.6 SILTSTONE: Light gray; moist;

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: N. Dakota — SHEET 1 OF 3 — HOLE NO. DH 75-106

7-1337 (9-69) Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: North Dakota
HOLE NO. DH 75-106 — LOCATION: 2440' W. of SE Corner, Section 11, T. 144 N., R. 94 W. — GROUND ELEV: Altimeter 2344± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 10/21/75 — FINISHED: 11/4/75 — TOTAL DEPTH: 180.5 — BEARING: —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 67.1' 11/4/75 (2276.9') — LOGGED BY: Taucher — LOG REVIEWED BY:

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole at 133.5' 10/24/75. 6" Ca at 24.5'. W.L. at 53.7'. 2-3/4" wire line core 133.5 to 160.8'. Losing 50 gallons of water per minute from 150.7 to 160.8'. Using revert.

Hole at 160.8' 11/3/75. 6" Cs at 24.5'. W.L. at 68.6'. 2-3/4" wire line core 160.8 to 180.5'. Losing 40 gallons of water per minute. Sample 172.1 to 179.8' washed away. Hole completed at 180.5'

11/4/75 W.L. 67.1' below ground surface. Backfilled hole with pea gravel. Cleaned up drill location.

5 pound lignite samples taken at the following intervals:
46.0 to 48.7'
51.0 to 53.6
121.9 to 124.6
129.5 to 131.4
134.7 to 137.3
140.3 to 142.8
146.1 to 148.7

Soils analysis sample, depth (feet):

Sample	From	To
#7	98.3	121.6 (Minus lignite)
#8	125.1	128.6
#9	150.7	165.3
#10	165.3	180.5

Elevation / Depth (feet):

Elevation	Depth
2222.4	121.6
2218.9	125.1
2215.4	128.6
2193.3	150.7
2178.7	165.3
2163.5	180.5

Classification and physical condition:

laminated; trace of clay; low plasticity; soft; cuts easily with knife; scattered marcasite inclusions.

76.6-78.2 LIGNITE WITH SILTSTONE: Black lignite with dark gray soft clayey siltstone 77.1 to 77.2, 77.4 to 77.5 & 77.6 to 78.0'; moist; 80° joint 76.6 to 77.1'; horizontal slickenside at 78.2'; 2 to 3" core lengths.

78.2-81.3 SHALE & SILTY SHALE: Medium gray; moist; plastic; becoming silty & less plastic with depth; moderately firm but cuts easily with knife; numerous 60 to 70° slickensides 78.2 to 79.2'; core lengths 3 to 6".

81.3-82.2 LIMESTONE: Medium gray; hard; cemented; scratches with knife; active HCl reaction; 1 to 2" core lengths.

82.2-98.3 SANDSTONE: Light gray; moist; uncemented; crumbles easily between fingers; fine grain; some silt; bedding not readily discernible; alternating low plasticity clayey siltstone & clayey sandstone laminations 82.2 to 83.2'; silty shale 83.8 to 83.9'; slight HCl reaction; core lengths 6 to 12".

98.3-121.6 SILTY SHALE & SANDSTONE: Medium gray; moist; firm; shales are silty, firm & moderately plastic (difficult trimming by knife); sandstones are fine grain, silty & generally crumble between fingers; shales below 111.0' are more plastic & tend to air slack; 55° joint at 115.6'; 45° slickenside at 119.4' partly filled with marcasite nodules; 45° slickenside at 120.4'; core lengths 2 to 18"; silty shale 98.3 to 98.6, 99.8 to 100.8, 101.2 to 101.4, 101.5 to 102.8, 103.6 to 106.6, 108.0 to 109.2, 111.0 to 116.7 & 117.7 to 121.6'; alternating laminations of silty shale & sandstone 98.6 to 99.3, 102.8 to 103.6 & 106.8 to 108.0'; sandstone 100.8 to 101.2, 101.4 to 101.5 & 109.2 to 111.0'; hard, claystone concretion 99.3 to 99.8'; lignite 116.6 to 117.7'.

121.6-125.1 LIGNITE: Black; very hard.

125.1-128.6 SILTY SHALE: Dark gray with ½ to 1" lignite streaks 125.1 to 125.8'; light gray 125.8 to 127.6'; dark gray & lignitic 127.6 to 128.6'; moist; firm; trims by knife with difficulty; moderately plastic; air slacks; 5 - 45° to 80° slickensides & joints 125.8 to 127.6'; numerous 10 to 15° slickensides 127.6 to 128.6'; core lengths 2 to 6".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: N. Dakota — SHEET 2 OF 3 — HOLE NO. DH 75-106

7-1337 (9-69) Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: North Dakota
HOLE NO. DH 75-106 — LOCATION: 2440' W. of SE Corner, Section 11, T. 144 N., R. 94 W. — GROUND ELEV: Altimeter 2344± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 10/21/75 — FINISHED: 11/4/75 — TOTAL DEPTH: 180.5 — BEARING: —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 67.1' 11/4/75 (2276.9') — LOGGED BY: Taucher — LOG REVIEWED BY:

Classification and physical condition:

128.6-150.7 LIGNITE: Black to dark brown; occasional 80° hairline fractures; hard; wet; broken along bedding planes on 1 to 8" centers.

150.7-165.3 SILTY SHALE: Dark gray & lignitic 150.7 to 151.7'; light gray 151.7 to 158.0'; medium gray 158.0 to 164.8'; moist; firm; difficult trimming by knife; moderately plastic; laminated siltstone, shale & sandstone 164.5 to 165.3'; numerous irregular slickensides 150.7 to 151.7'; 60° slickenside at 152.0'; 45° joint at 154.2'; 90° joint at 161.8'; core lengths 3 to 12".

165.3-180.5 SANDSTONE: Light gray; moist; uncemented; crumbles easily between fingers; medium gray siltstone & silty shale laminations 165.3 to 169.0'; fine grain sandstone 169.0 to 180.5'; sample 172.1 to 179.8' washed away during drilling; core length 2 to 12".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: N. Dakota — SHEET 3 OF 3 — HOLE NO. DH 75-106

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

GEOLOGIC LOG OF DH 75-106

GEOLOGY: G. TAUCHER — SUBMITTED:
DRAWN: — RECOMMENDED:
CHECKED: — APPROVED:

BILLINGS, MONT. — MAY 1976 — 1305-600-88

GEOLOGIC LOG OF DRILL HOLE — Sheet 1 of 2

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field · PROJECT: EMRIA No. 9 · STATE: North Dakota
HOLE NO.: DH 75-107 · LOCATION: 1710' N. & 1100' E. of SW Corner, Section 12, T. 144 N., R. 94 W. · GROUND ELEV.: Altimeter 2273± · DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 11/19/75 · FINISHED: 11/21/75 · TOTAL DEPTH: 103.8 · BEARING: —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 33.6' 12/8/75 (2239.4) · LOGGED BY: Taucher · LOG REVIEWED BY:

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole started 11/19/75. Nx drive samples 0 to 15.0'. Nx rotation 15.0 to 20.0'. 2-3/4" wire line core 20.0 to 43.8'. 5 gallon per minute water loss below 27.3'. Using revert. Set 6" Cs to 5.0'.

Hole at 43.8' 11/20/75. 6" Cs at 5.0'. W.L. at 26.8'. Reamed hole 0 to 43.0' with 5-1/8" drag bit. Using revert. 2-3/4" wire line core 43.8 to 103.8'. Lost core 46.8 to 48.3 & 56.9 to 58.6' (unable to recover). Dropped core 76.8 to 83.8' (recovered 4.6' of core).

Classification and physical condition:

0-0.7 SILTY SAND: Dark grey; dry; organic; roots; approximately 25% very low plasticity fines & 75% fine, uniform sand (SM); wind blown.

SENTINEL BUTTE FORMATION - PALEOCENE

0.7-11.8 CLAYEY SILTSTONE: Brown; damp; oxidized; highly weathered; almost disintegrated to soil; slight plasticity; calcareous (caliche) 3.0 to 8.0'; crumbles easily between fingers; soft, broken lignite 11.0 to 11.2'; 1 to 3" core lengths.

11.8-37.6 SHALE WITH CLAYEY SILTSTONE & SILTY SHALE: Shales are tan to medium grey, firm (trim by knife with difficulty), plastic & generally air slack; sandstones are tan, slightly calcareous, fine grain, silty & crumble easily between fingers; siltstones are clayey to sandy & crumble easily between fingers; moist; oxidized 11.8 to 36.0'; core lengths 2 to 24".
- 11.8-18.0 - Plastic shale.
- 18.0-19.0 - Clayey sandstone, about 40% clay.
- 19.0-27.3 - Plastic shale; ¼" coal film [illegible] 45° fracture at 21.2'; 45° joint at 21.[illegible]'.
- 27.3-28.1 - Black, soft lignite at 27.[illegible] to 27.8' & dark grey, plastic, lignitic shale 27.8 to 28.1'; gypsum crystals [illegible] 28.1'.
- 28.1-28.5 - Plastic shale.
- 28.5-30.8 - Laminated clayey siltstone & silty shale.
- 30.8-35.3 - Laminated very fine grain silty sandstone & sandy siltstone.
- 35.3-37.6 - Plastic shale.

37.6-45.4 LIGNITE: Banded black & dark brown; moist to wet; upper half badly broken; lower half 1 to 6" core lengths; breaks along bedding planes.

45.4-56.0 SHALE: Medium grey; moist; plastic; air slacks; occasional ¼" marcasite nodules generally along bedding planes; slightly calcareous 55.2 to 56.0'; firm; trims by knife with difficulty; lost sample 46.8 to 48.3'; core lengths 6 to 24".

56.0-73.8 LIGNITE: Banded black to dark brown; moderately broken along bedding planes on ½ to 3" centers; moist to wet; hard.

73.8-93.8 SHALE: [illegible] plastic; firm; trims by knife with some difficulty; bedding not discernible; carbonaceous sandy shale 73.8 to 74.8' with ½" lignite at 74.1'; laminated silty shale & clayey siltstone 92.5 to 92.8 &

EXPLANATION

GEOLOGIC LOG OF DRILL HOLE — Sheet 2 of 2

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field · PROJECT: EMRIA No. 9 · STATE: North Dakota
HOLE NO.: DH 75-107 · LOCATION: 1710' N. & 1100' E. of SW Corner, Section 12, T. 144 N., R. 94 W. · GROUND ELEV.: Altimeter 2273± · DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 11/19/75 · FINISHED: 11/21/75 · TOTAL DEPTH: 103.8 · BEARING: —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 33.6' 12/8/75 (2239.4) · LOGGED BY: Taucher · LOG REVIEWED BY:

Notes:

Hole at 103.8' 11/21/75. 6" Cs at 5.0'. W.L. at 14.4'. Pulled 6" Cs & moved rig.

12/8/75. W.L. at 33.6' (2239.6')

5 pound lignite samples taken at the following intervals:
38.0 to 40.9'
58.6 to 61.3
64.0 to 66.7
69.0 to 71.7

Classification and physical condition:

93.0 to 93.8'; uncemented, fine grain sandstone 92.8 to 93.0'; 80 to 90° joints at 82.8 to 83.8 & 84.2 to 85.2'; core lengths 2 to 24".

93.8-103.8 SANDSTONE: Light grey; moist; fine grain; uncemented; crumbles easily between fingers; trace of silt; fair cohesion; bedding not discernible; core lengths 2 to 12".

EXPLANATION

GEOLOGIC LOG OF DRILL HOLE — Sheet 1 of 2

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field · PROJECT: EMRIA No. 9 · STATE: North Dakota
HOLE NO.: DH 75-108 · LOCATION: 1980' E. of SW Corner, Section 12, T. 144N., R. 94 W. · GROUND ELEV.: Altimeter 2249± · DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 11/4/75 · FINISHED: 11/6/75 · TOTAL DEPTH: 103.5 · BEARING: —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 16.6' 11/21/75 (2232.4) · LOGGED BY: Taucher · LOG REVIEWED BY:

Notes:

Hole started 11/4/75. Nx drive samples 0 to 15.0'.

Hole at 15.0' 11/5/75. Hole dry. 2-3/4" wire line core 15.0 to 53.2'. Hole squeezing in. Pulled wire line and reamed hole to 53.3' with 5-1/8" rockbit. Losing about 15 gallons of water per minute. 2-3/4" wire line core 53.3 to 73.5'. 6" Cs set to 10.0'. Using revert.

Hole at 73.5' 11/6/75. 6" Cs at 10.0'. W.L. at 16.8'. 2-3/4" wire line core 73.5 to 103.5'. Little or no water loss. Hole completed. Pulled 6" Cs.

Classification and physical condition:

0-8.0 SANDY CLAY: Dark brown and slightly organic 0 to 1.0'; tan with some caliche 2.5 to 3.5'; dark grey to brown and slightly organic 3.5 to 8.0'; active acid reaction 3.5 to 8.0'; dry; approximately 40% fine, uniform sand with occasional coarse sand and 60% low to medium plasticity fines; lower 1.0' could be residual weathered shale; probably wind blown (CL).

SENTINEL BUTTE FORMATION - PALEOCENE

8.0-20.3 SILTY SHALE: Brown becoming grey-brown with depth; oxidized; moist; moderately firm; trims easily by knife; bedding not readily discernible; moderately plastic; uncemented silty sandstone 11.0 to 11.5'; gypsum inclusions 8.0 to 10.0'; hard, claystone concretion 16.5 to 16.7'; air slakes; core lengths 6 to 18".

20.3-21.7 LIGNITE: Black; hard; few 1/8" shale streaks 20.3 to 20.4'; 2 to 6" core lengths.

21.7-26.0 SILTY SHALE: Medium grey; moist; moderately firm; cuts easily with knife; thin-bedded; moderately plastic; ¼" lignite at 23.0'; several lignite inclusions 21.7 to 23.0'; core lengths 6 to 12".

26.0-31.6 SILTY SANDSTONE WITH SILTY SHALE: Sandstone is light grey, fine grain and silty (crumbles easily between fingers); silty shale is moderately plastic, firm and trims easily with knife; moist; sandstone is generally laminated; bedding not readily discernible in shale; silty sandstone except silty shale 28.3 to 28.6, 29.1 to 29.2, 29.5 to 29.7, 30.2 to 30.3 and 31.2 to 31.3'; 1/8" lignite at 27.0'; core lengths 6 to 12".

31.6-34.1 SILTY SHALE: Medium grey; moist; moderately firm; trims by knife easily; bedding not readily discernible; moderately plastic to plastic; silty sandstone 32.2 to 32.3'; core lengths 2 to 12".

34.1-43.3 LIGNITE: Black; broken along bedding planes in 1 to 3" pieces.

43.3-58.4 SHALE: Medium grey; moist; firm; trims by knife with difficulty; plastic; bedding not readily discernible; broken along 70° joint at 45.0'; ¼" lignite inclusions at 47.1 and 57.2'; dark grey and carbonaceous 57.4 to 58.[illegible]'; several ¼" lignite streaks 58.2 to 58.[illegible]'; air slakes; 8 to 18" core lengths.

EXPLANATION

GEOLOGIC LOG OF DRILL HOLE — Sheet 2 of 2

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field · PROJECT: EMRIA No. 9 · STATE: North Dakota
HOLE NO.: DH 75-108 · LOCATION: 1980' E. of SW Corner, Section 12, T. 144N., R. 94 W. · GROUND ELEV.: Altimeter 2249± · DIP (ANGLE FROM HORIZ.): Vertical
BEGUN: 11/4/75 · FINISHED: 11/6/75 · TOTAL DEPTH: 103.5 · BEARING: —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 16.6' 11/21/75 (2232.4) · LOGGED BY: Taucher · LOG REVIEWED BY:

Notes:

5 pound lignite samples taken at the following intervals:
34.6 to 37.2'
58.8 to 60.6
64.3 to 66.6
71.2 to 73.5

11/21/75 W.L. at 16.6'. Backfilled hole with pea gravel.

Classification and physical condition:

58.4-76.2 LIGNITE: Banded, black and dark brown; hard; badly broken 61.5 to 63.5'; remaining core is in 2 to 12" lengths.

76.2-98.0 SILTY SHALE: Medium grey; moist; moderately firm; trims easily with knife; moderately plastic to plastic; bedding not readily discernible except laminated 90.5 to 93.6 and 95.5 to 97.5'; ¼" lignite filled 70° fracture (?) at 77.1'; hard lignite 81.7 to 82.4'; lignite shale 82.4 to 82.7'; lignite 89.4 to 89.6'; laminated shale with 1/8 to 1/4" lignite streaks 90.5 to 93.6' (10% of zone is lignite); lignite 97.3 to 97.5'; 50° joint at 85.4, 87.7 and 88.2'; core lengths 6 to 18".

98.0-103.5 SILTY SANDSTONE: Laminated light to medium grey; moist; uncemented; crumbles easily between fingers; very fine grain; may be sandy siltstone in places; trace of clay; generally slightly plastic; moderately firm, silty shale 102.5 to 103.5'; occasional marcasite inclusions; core lengths 3 to 18".

EXPLANATION

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

GEOLOGIC LOGS OF DH 75-107 & 108

GEOLOGY: B. TAUCHER · SUBMITTED:
DRAWN: · RECOMMENDED:
CHECKED: · APPROVED:
BILLINGS, MONT. · MAY 1976 · 1305-600-89

GEOLOGIC LOG OF DRILL HOLE

7-1331 (9-66) Bureau of Reclamation — SHEET 1 OF 3

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT EMRIA No. 9 — STATE North Dakota
HOLE NO. DH 75-109 — LOCATION 850' S. of NW Corner, Section 15, T. 144 N., R. 94 W. — GROUND ELEV. 2307± (Hand Level) — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 11/24/75 — FINISHED 12/3/75 — TOTAL DEPTH 161.0 — BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 120.7' 12/15/75 (2186.3) — LOGGED BY Taucher — LOG REVIEWED BY

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole started 11/24/75. Nx drive samples 0 to 10.0'.

Hole at 10.0' 11/25/75. Hole dry. Nx drive samples 10.0 to 15.0'. 2-3/4" wire line core 15.0 to 53.4'. Set 6" Cs to 5.0'. Reamed hole to 43.4' to 5-1/8". Losing some water before using revert 27.0 to 43.4'. Lost some core from bottom of run 24.1 to 33.4'.

Hole at 53.4'. 11/26/75. W.L. at 2.0'. 6" Cs at 5.0'. 2-3/4" wire line core 53.4 to 83.4'. Using revert. Little or no water loss.

Hole at 83.4'. 12/1/75. W.L. at 43.4'. 6" Cs at 5.0'. 2-3/4" wire line core 83.4 to 93.4'. Using revert.

Hole at 93.4'. 12/2/75. W.L. at 16.0'. 6" Cs at 5.0'. 2-3/4" wire line core 93.4 to 122.8'. Using revert. No drill water loss.

Core recovery (%): 100, 100, 100, 100, 100, 83, 100, 100, 100, 100, 100, 100, 100

Soils analysis sample	From	To
#1	3.0	21.5
#2	21.5	24.0
#3	24.1	38.6
#4	38.6	98.7

Elevation (feet)	Depth (feet)
2304.0	3.0
2285.5	21.5
2283.0	24.0
2282.9	24.1
2268.4	38.6
2208.3	98.7

Classification and physical condition:

0-3.0 SILTY SAND: Brown and slightly organic with roots 0 to 1.5'; tan and oxidized 1.5 to 3.0'; dry to damp; soft; approximately 80% fine, uniform sand and 20% nonplastic fines; slight HCl reaction; wind blown (SM).

SENTINEL BUTTE FORMATION - PALEOCENE

3.0-21.5 CLAYEY SILTSTONE: Tan to gray-brown; dry to damp; oxidized; moderately firm; crumbles easily between fingers; laminated; broken & highly weathered 3.0 to 17.0'; moderately weathered and broken in 1 to 3" pieces 17.0 to 21.5'; moderately plastic; approaching silty shale; slight HCl reaction with active HCl reaction along white calcareous deposits in high angle fractures 3.0 to 4.0 and 9.0 to 10.0'; plastic silty shale 3.0 to 5.0'; lignite 15.2 to 15.3'; lignite 15.5 to 15.6'; highly oxidized with several slickensides 15.2 to 15.6'; occasional small gypsum inclusions especially between 19.0 and 15.0'.

21.5-24.0 SANDSTONE: Tan to light gray; slightly oxidized; moist; fine grain; uncemented; near clean; crumbles easily between fingers; bedding not discernible except laminated light and dark gray carbonaceous sandstone 22.0 to 22.3'; slight HCl reaction; core pulverized by drilling.

24.0-24.1 LIGNITE: Black; soft; broken.

24.1-38.6 SILTY SHALE AND SILTSTONE: Gray-brown and oxidized 24.1 to 25.3'; light gray to tan and slightly oxidized 25.3 to 38.6'; damp; shales are moderately firm and trim easily by knife; siltstones are uncemented and crumble easily between fingers; laminated; very slight HCl reaction; core lengths 1 to 12".

24.1-25.3 - Moderately plastic silty shale with occasional ½" lignite and gypsum inclusions.

25.3-33.4 - Very low plasticity siltstone; 2-1/4" lignite streaks 27.0 to 27.1'.

33.4-37.0 - Moderately plastic silty shale with 3-1/8 to 1/4" lignite streaks 36.5 to 36.7'; oxidized around weathered, gypsum lined, 90° joint 33.4 to 35.4'; 60° slickenside at 36.4'.

37.0-38.6 - Low plasticity clayey siltstone; highly oxidized, gypsum lined (1/8") joint 37.4 to 38.4'.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series). Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field ... PROJECT EMRIA No. 9 .. STATE N. Dakota .. SHEET 1 OF 3 . HOLE NO. DH 75-109

GEOLOGIC LOG OF DRILL HOLE

7-1331 (9-66) Bureau of Reclamation — SHEET 2 OF 3

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT EMRIA No. 9 — STATE North Dakota
HOLE NO. DH 75-109 — LOCATION 850' S. of NW Corner, Section 15, T. 144 N., R. 94 W. — GROUND ELEV. 2307± (Hand Level) — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 11/24/75 — FINISHED 12/3/75 — TOTAL DEPTH 161.0 — BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 120.7' 12/15/75 (2186.3) — LOGGED BY Taucher — LOG REVIEWED BY

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole at 122.8' 12/3/75. W.L. at 34.2'. 6" Cs at 5.0'. 2-3/4" wire line core 122.6 to 161.0'. 20 gallon per minute water loss 125.0 to 161.0'. Using revert. Pulled 6" Cs. Hole completed at 161.0'.

12/15/75. W.L. at 120.7' (2186.3). Backfilled hole with pea gravel.

5 pound lignite samples taken at the following intervals:
114.4 to 116.9'
120.2 to 122.8
125.3 to 128.0

Core recovery (%): 83, 100, 100, 100, 100, 100, 100

Soils analysis sample	From	To
#5	98.7	105.2
#6	128.5	140.8
#7	140.8	161.0

Elevation (feet)	Depth (feet)
2201.8	105.2
2198.8	108.2
2195.3	111.7
2178.5	128.5
2166.2	140.8
2146.0	161.0

Classification and physical condition:

38.6-98.7 SILTY SANDSTONE: Light gray to tan; slightly oxidized; moist to wet; fine grain; uncemented; crumbles easily between fingers; generally pulverized; almost like river sand; no HCl reaction.

38.6-40.0 - Silty, very fine grain sandstone; bedding not discernible.

40.0-41.7 - Low plasticity clayey siltstone; trims easily by knife; bedding not discernible.

41.7-55.2 - Alternating laminations of silty, very fine grain sandstone and low plasticity sandy siltstone; oxidized moderately plastic shale 54.7 to 55.0'.

55.2-75.7 - Fine grain, uncemented sandstone; trace of silt; bedding not discernible; highly oxidized around 80° joint 71.6 to 72.2'.

75.7-94.0 - Fine grain sandstone with ¼ to 3" laminated silty sandstone or clayey siltstone streaks on 3 to 6" centers; 1" circular marcasite nodule at 85.5'.

94.0-98.7 - Fine grain, uncemented sandstone; bedding not discernible; several gypsum crystals at 98.7'.

98.7-105.2 SHALE WITH SANDSTONE: Shale is moderately firm, plastic, carbonaceous in places and trims easily by knife; sandstone is fine grain, brown, oxidized and crumbles easily between fingers; oxidized sandstone streaks 99.4 to 99.5, 99.7 to 99.9, 100.3 to 100.5, 101.6 to 101.9, 102.0 to 102.2, 102.4 to 102.6 and 103.4 to 103.6'; alternating laminations of dark gray, slightly carbonaceous, plastic shale and tan oxidized, uncemented sandstone 104.0 to 105.2'; occasional gypsum crystals at shale-sandstone contacts; core lengths 1 to 12".

105.2-108.2 SANDSTONE: Tan; moist; slightly oxidized; fine grain; uncemented; crumbles easily between fingers; generally pulverized by drilling; plastic shale 107.2 to 107.3'.

108.2-111.7 SHALE: Dark gray to black; moist; moderately firm; trims easily by knife; moderately plastic to plastic; bedding not readily discernible; black broken, soft lignitic shale and lignite 108.2 to 108.8' (bottom contact is 60° slickenside); dark gray plastic shale 108.8 to 109.8' with 50° slickenside at 109.2' and 30° slickenside at 109.8'; black lignitic, plastic shale 109.8 to

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series). Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field ... PROJECT EMRIA No. 9 . STATE N. Dakota . SHEET 2 OF 3 . HOLE NO. DH 75-109

GEOLOGIC LOG OF DRILL HOLE

7-1331 (9-66) Bureau of Reclamation — SHEET 3 OF 3

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT EMRIA No. 9 — STATE North Dakota
HOLE NO. DH 75-109 — LOCATION 850' S. of NW Corner, Section 15, T. 144 N., R. 94 W. — GROUND ELEV. 2307± (Hand Level) — DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 11/24/75 — FINISHED 12/3/75 — TOTAL DEPTH 161.0 — BEARING --
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 120.7 12/15/75 (2186.3) — LOGGED BY Taucher — LOG REVIEWED BY

Classification and physical condition:

111.7' with highly oxidized sandstone containing numerous gypsum crystals 110.6 to 110.7'; core lengths 2 to 12".

111.7-128.5 LIGNITE: Black; wet; broken along bedding planes on 1 to 8" centers; occasional 90° hairline fracture; scattered gypsum crystals 111.7 to 112.3'.

128.5-140.8 SILTY SHALE: Mostly light gray; moist; moderately firm; cuts easily with knife; bedding not discernible 128.5 to 135.5'; laminated and more silty 135.5 to 140.8'; brown to dark gray, slightly oxidized and lignitic 128.5 to 130.0'; light gray to tan and slightly oxidized 130.0 to 134.5' with dark gray lignitic shale 134.3 to 134.5'; broken lignite 134.5 to 135.2'; alternating laminations of shale and silty shale 135.2 to 140.8'; 70° joint with associated 30 to 40° slickensides 130.5 to 131.5'; several 15 to 20° slickensides above lignite 134.3 to 134.5'; moderately plastic; begins to air slake in places; core lengths 3 to 12".

140.8-161.0 SILTY SANDSTONE AND SANDSTONE: Light gray; moist to wet; uncemented; fair cohesion; crumbles easily between fingers; silty and very fine grain 140.8 to 147.4'; fine grain and near clean 147.4 to 161.0'; bedding not discernible; several small (-½") marcasite nodules 140.8 to 147.4'; 80 to 90° tight joints 149.4 to 151.0'; begins to wash away in places during drilling.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series). Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field ... PROJECT EMRIA No. ... STATE N. Dakota . SHEET 3 OF 3 . HOLE NO. DH 75-109

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

GEOLOGIC LOG OF DH 75-109

GEOLOGY G. TAUCHER — SUBMITTED
DRAWN — RECOMMENDED
CHECKED — APPROVED

BILLINGS, MONT. MAY 1976 — 1305-600-90

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 1

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT EMRIA No. 9 — STATE North Dakota

HOLE NO. DH 76-110 — LOCATION 2400' N. of SW Corner, Sec. 10, T. 144 N., R. 94 W. — GROUND ELEV. 2251± (Hand Level) — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 1/19/76 — FINISHED 1/21/76 — TOTAL DEPTH 80.6 — BEARING --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 41.1' 2/2/76 (2209.9) — LOGGED BY Taucher — LOG REVIEWED BY

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

1/19/76 Moved to DH 76-110.

Hole started 1/20/76. Nx drive samples 0 to 15.0'. 2-3/4" wire line core 15.0 to 43.5'. Set 6" Cs to 5.0'. Using revert. No water loss.

Hole at 43.5' 1/21/76. 6" Cs at 5.0'. W.L. at 41.0'. 2-3/4" wire line core 43.5 to 80.6'. Using revert. No drill water loss. Pulled 6" Cs. Hole completed.

2/2/76 W.L. at 41.1' (2209.9). Hole backfilled with pea gravel.

5 pound lignite samples taken at the following intervals:
53.0 to 56.0'
60.0 to 63.5'

Soils analysis samples: #1 0.5 to 47.8; #2 66.6 to 78.7

Elevation / Depth: 2250.5 / 0.5; 2203.2 / 47.8; 2184.4 / 66.6; 2172.3 / 78.7; 2170.4 / 80.6

Classification and physical condition:

0-0.5 SILTY SAND: Dark grey; moist; roots; organic; approximately 40% very low plasticity fines and 60% very fine, uniform sand (SM-SC).

SENTINEL BUTTE FORMATION - PALEOCENE

0.5-47.8 SILTY SANDSTONE: Tan; slightly oxidized; dry becoming moist with depth; active HCl reaction (caliche) 0.5 to 3.5'; fine to very fine grain; uncemented; very little cohesion; crushes easily between fingers; bedding not generally discernible: clayey siltstone 8.5 to 10.0 and 13.5 to 14.0'; sand is 200 sieve 0.5 to 15.0 and 21.5 to 47.8'; 100 to 50 sieve sand 15.0 to 21.5'; scattered thin (1/8") carbonaceous streaks 43.5 to 47.8'.

47.8-66.6 LIGNITE: Banded black and dark brown; moist to wet; soft and badly broken 47.8 to 54.5'; moderately broken along bedding planes on 1 to 10" centers 54.5 to 66.6'.

66.6-78.7 SHALE: Medium to dark grey; moist; moderately firm; trims by knife with some difficulty; plastic; air slakes; thin-bedded to laminated; black, lignitic shale 66.6 to 66.9'; alternating streaks of medium gray shale and dark gray lignitic shale 66.9 to 68.4'; 70° slickensides with ¼" to ½" of lignite at 68.5 and 69.2'; 5-45° to 65° slickensides 69.2 to 70.6'; lignite 70.6 to 71.6 and 71.9 to 72.1'; horizontal slickensides in lignitic shale 74.8 to 75.0'; occasional small marcasite inclusion; core lengths 1 to 18".

78.7-80.6 SHALEY SANDSTONE: Alternating laminations of light gray fine grain sandstone and medium gray plastic shale (shale about 30%); cuts easily with knife and crumbles between fingers with difficulty; uncemented; core lengths 2 to 6".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT EMRIA No. 9 — STATE N. Dakota — SHEET 1 OF 1 — HOLE NO. DH 76-110

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 1

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT EMRIA No. 9 — STATE North Dakota

HOLE NO. DH76-111 — LOCATION 1960' E & 85' S of N.W. Corner, Section 10, T. 144 N., R. 94 W. — GROUND ELEV. 2247± (Hand Level) — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 1/23/76 — FINISHED 1/29/76 — TOTAL DEPTH 91.5 — BEARING --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 70.0' 2/6/76 (2177.0) — LOGGED BY Taucher — LOG REVIEWED BY

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole started 1/23/76. Nx drive samples 0 to 10.0'.

Hole at 10.0' 1/26/76. Hole dry. Nx drive samples 10 to 19.0'. Set 6-in. Cs to 5.0'.

Hole at 19.0' 1/27/76. 6-in. Cs at 33.0'. Hole dry. 2-3/4-in. wireline core 19.0 to 34.2'. Lost all drill water in void 28.5 to 30.9'. Washed away core 30.9 to 34.2'. Advanced 6-in. Cs to 33.0'.

Hole at 34.2' 1/28/76. 6-in. Cs at 33.0'. W.L. at 8.0'. 2-3/4 in. wireline core 34.2 to 43.0'. Lost core 41.0 to 42.2'. Void 42.2 to 43.0'. Lost all drill water (50 G.P.M.) 42.2'-43.0'. Nx drive samples 43.0 to 46.0'. Set NxCs to 45.6'. Nx core 46.0 to 56.0'. 30 G.P.M. waterloss 53.0 to 56.0'. Advanced NxCs to 55.4'. Nx core 56.0 to 71.6'.

Hole at 71.6' 1/29/76. 6-in. Cs at 33.0'. NxCs at 55.4'. W.L. at 24.6'. Nx core 71.6 to 91.5'. Using revert. No water loss. Hole completed. Pulled Nx & 6-in. Cs. Moved rig to DH76-118.

5-pound lignite samples taken at the following intervals:
67.0 to 70.0'
73.0 to 76.0
77.3 to 81.6
86.7 to 88.8

Soils analysis samples: #1 2.4 to 6.8; #2 6.8 to 60.9; #3 60.9 to 66.5; #4 83.6 to 90.0 minus lignite

Elevation / Depth: 2244.6 / 2.4; 2240.2 / 6.8; 2186.1 / 60.9; 2180.5 / 66.5; 2163.4 / 83.6; 2157.0 / 90.0; 2155.5 / 91.5

Classification and physical condition:

0-2.4 SILTY SAND: dark gray; moist; slightly organic; few roots; approximately 15% non plastic fines and 85% fine uniform sand; wind deposited (SM).

SENTINEL BUTTE FORMATION - PALEOCENE

2.4-6.8 CLAYEY SILTSTONE: tan 2.4 to 6.0'; yellow-brown and highly oxidized 6.0 to 6.8'; dry to damp; uncemented; crushes between fingers with some difficulty; active HCl reaction in zones; low plasticity; laminated in zones; streaks of cemented sandstone 6.0 to 6.8'; broken in 1 to 12-in. pieces.

6.8-60.9 SANDSTONE: tan and slightly oxidized; dry becoming moist with depth; fine grain; uniform; scattered streaks of laminated sandy siltstone 9.0 to 12.0'; crumbles easily between fingers; uncemented; generally near clean; 1/8-in. lignite bands at 35.9, 36.0, 36.3 & 37.0'; soft clayey sandstone (35% medium plasticity fines) 53.2 to 53.7, 54.8 to 55.0 & 55.5 to 56.0'; silty sandstone with 1 to 3-in. laminated clayey siltstone stringers 56.0 to 60.9'; ½-in. marcasite nodule along bedding plane at 60.8'; probably open joints where driller reported voids 28.5 to 30.9 and 42.2 to 43.0' generally pulverized.

60.9-66.5 SILTY SHALE: light to medium gray; moist; moderately soft; trims easily with knife; laminated; moderately plastic; clayey siltstone 64.0 to 65.0'; very soft, dark gray carbonaceous shale 66.0 to 66.5'; core lengths 6 to 18 in.

66.5-83.6 LIGNITE: banded black to dark brown; moderately hard; broken along bedding planes on 2-to 6-in. centers; 2-60° fractures 82.6 to 83.6'.

83.6-90.0 SHALE: medium gray; moist; moderately soft; trims easily with knife; plastic; air slakes; 1 x 6 in. lignite fragment with associated slickensides 84.4 to 85.0'; ½-in. lignite (dip 25°) at 85.5'; hard lignite 86.5 to 88.8'; 70° slickensides at 89.5 and 89.[illegible]'; core lengths 3 to 6 in.

90.0-91.5 SILTSTONE: banded light gray sandy siltstone and medium gray clayey siltstone; moist; moderately soft; crumbles easily between fingers; uncemented; sand is fine grain and uniform; clay is moderately plastic; core lengths 2 to 6 in.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT EMRIA No. 9 — STATE N. Dakota — SHEET 1 OF 1 — HOLE NO. DH76-111

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 1

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT EMRIA No. 9 — STATE North Dakota

HOLE NO. DH75-112 — LOCATION 1500' S. & 2600' E. of NW Corner, Section 12, T. 144 N., R. 94 W. — GROUND ELEV. 2218± — DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 12/4/75 — FINISHED 12/9/75 — TOTAL DEPTH 55.0 — BEARING --

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 16.8' 12/19/75 (2201.2) — LOGGED BY Taucher — LOG REVIEWED BY

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole started 12/4/75. Set up rig. Nx drive samples 0 to 10.0'.

Hole at 10.0' 12/9/75. Set 6" Cs to 5.0'. Hole dry. Nx rotation 10.0 to 43.0'. Reamed hole 0 to 43.0' with 5-7/8" bit. 2-3/4" wire line core 43.0 to 55.0'. Using revert. Lost 6 gallons of water per minute 15.5 to 16.0'. Hole completed at 55.0'.

12/3/75 W.L. at 12.3'.

12/19/75 W.L. at 16.8' (2201.2'). Hole filled with pea gravel.

No lignite samples.

Soils analysis samples: No soils analysis samples taken

Elevation / Depth: 2214.0 / 4.0; 2202.5 / 15.5; 2202.0 / 16.0; 2174.0 / 44.0; 2163.0 / 55.0

Classification and physical condition:

0-4.0 SILTY SAND: Dark grey, organic with roots 0 to 1.5', tan and oxidized 1.5 to 4.0', dry approximately 20% nonplastic fines and 80% fine, uniform sand; wind deposited (SM).

4.0-15.5 SANDY CLAY: Tan becoming brown with depth. Dry 4.0 to 10.0'; moist 10.0 to 15.5'; oxidized; scattered white caliche deposits especially between 4.0 and 10.0'; approximately 55% medium plasticity fines, 40% mostly fine with some coarse sand and 5% fine, hard, subrounded, igneous gravel (maximum size 3/4"); numerous lignite fragments; glacial till.

SENTINEL BUTTE FORMATION - PALEOCENE

15.5-16.0 LIGNITE: Black; soft; broken.

16.0-44.0 SILTY SHALE: Tan and highly oxidized 16.0 to 28.0'; medium gray to tan and slightly oxidized 28.0 to 30.0'; medium grey and unoxidized 30.0 to 44.0'; moist to wet; soft becoming moderately firm with depth; trims easily with knife; laminated; moderately plastic to plastic; several thin, uncemented fine grain sandstone streaks 42.0 to 42.5'; core lengths 6 to 36".

44.0-55.0 SANDSTONE: Light gray; moist to wet; fine grain; near clean; uncemented; slight cohesion; crumbles easily between fingere; core lengths 6 to 12".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT EMRIA No. 9 — STATE N. Dakota — SHEET 1 OF 1 — HOLE NO. DH75-112

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

GEOLOGIC LOGS OF 76-110 & 111 & DH 75-112

GEOLOGY G. TAUCHER — SUBMITTED
DRAWN — RECOMMENDED
CHECKED — APPROVED
BILLINGS, MONT. — MAY 1976 — 1305-600-91

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 1

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: North Dakota

HOLE NO. DH75-113 — LOCATION: 1550' N. of SE Corner, Section 12, T. 144 N., R. 94 W. — GROUND ELEV: Hand Level 2226± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 12/10/75 — FINISHED: 12/12/75 — TOTAL DEPTH: 81.8 — BEARING: —

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 12.7' 12/19/75 (2213.3) — LOGGED BY: Taucher — LOG REVIEWED BY: —

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

Hole started 12/10/75. Nx drive samples 0 to 5.0'. Nx rotation 5.0 to 25.0'.
Hole at 25.0' 12/11/75. W.L. at ground level. Set 6" Cs to 5.0'. Reamed hole to 5-7/8" from 0 to 25.0'. 2-3/4" wire line core 25.0 to 63.4'. Using revert. No water loss. Lost core 50.0 to 53.3'.

Hole at 63.4' 12/12/75. W.L. at ground surface. 6" Cs at 5.0'. 2-3/4" wire line core 63.4 to 81.8'. Using revert. No drill water loss. Hole completed.

12/19/75 W.L. at 12.7' (2213.3). Hole filled with pea gravel.

5 pound lignite samples taken at the following intervals:
29.6 to 33.4'
37.0 to 39.8'
43.6 to 46.2'

Core recovery (%): 100, 90, 100, 100, 100, 100, 100, 100, 0, 100, 100, 100

Soils analysis samples (depth, feet):

Sample	From	To
#1	1.3	7.5
#2	7.5	29.0
#3	48.8	63.4
#4	63.4	71.1
#5	76.5	81.8

Elevation / Depth (feet): 2224.7 / 1.3; 2218.5 / 7.5; 2197.0 / 29.0; 2177.2 / 48.8; 2162.6 / 63.4; 2154.9 / 71.1; 2152.1 / 73.9; 2149.5 / 76.5; 2144.2 / 81.8

Classification and physical condition:

0-1.3 SANDY CLAY: Dark brown; moist; organic; few roots; soft; approximately 60% low to medium plasticity fines and 40% fine, uniform sand (CL).

SENTINEL BUTTE FORMATION - PALEOCENE

1.3-7.5 CLAYEY SILTSTONE: Brown; moist; oxidized; soft; highly weathered; scattered white caliche deposits; occasional gypsum inclusions; low plasticity; moderately plastic, soft silty shale 2.2 to 3.2' badly broken by drilling; thin-bedded to laminated.

7.5-29.0 SILTY SHALE: Brown, oxidized and very soft 7.5 to 25.0' (indents with finger); dark gray, unoxidized and firm 25.0 to 29.0' (trims by knife with difficulty); moist; moderately plastic to plastic; very slight acid reaction; bedding not readily discernible; occasional gypsum crystals 7.5 to 9.5'; pulverized in oxidized zone; 12 to 18" core lengths 25.0 to 29.0'; air slakes below 25'.

29.0-48.8 LIGNITE: Banded black to dark brown; moist; firm to almost hard; broken along bedding planes on 1 to 6" centers.

48.8-63.4 SHALE: Medium gray; moist; moderately firm; cuts by knife with difficulty; very slight HCl reaction in zones; thin-bedded to almost laminated in places; air slakes; plastic; shattered 48.8 to 50.6'; irregular 30 to 45° slickensides at 57.7'; 30° slickenside at 58.7'; broken lignite 53.8 to 54.8 and 58.8 to 59.1'; core lengths 6 to 12".

63.4-71.1 SILTY SANDSTONE: Laminated light to medium gray; silty, very fine grain sand; trace of clay (very low plasticity); moist; uncemented; crumbles between fingers; scattered ¼ to ½" marcasite nodules; very slight HCl reaction; fine grain, uncemented sandstone 70.4 to 71.1'; 3 to 18" core lengths.

71.1-73.9 SHALE: Medium gray; moist; moderately firm; trims easily by knife; bedding not discernible; plastic; air slakes; 6 to 24" core lengths.

73.9-76.5 SANDSTONE, SILTY SANDSTONE AND SILTY SHALE: 73.9-75.1 light gray, fine grain, uncemented sandstone, crumbles between fingers. 75.1-75.8 laminated light to medium gray, silty, fine grain, uncemented sandstone; trace of clay. 75.8-76.2 medium gray, moderately plastic, soft silty shale. 76.2-76.5 fine grain, uncemented sandstone.

76.5-81.8 SHALE: Medium gray; moist; firm; trims by knife with difficulty; plastic; air slakes; bedding not readily discernible; ½ to 1" hard, claystone concretions at 76.7, 78.6 and 80.2'; core lengths 6 to 12".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: N. Dakota — SHEET 1 OF 1 — HOLE NO. DH75-113

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: North Dakota

HOLE NO. DH 76-114 — LOCATION: 2500' S. of NW Corner Sec. 11, T. 144 N., R. 94 W. — GROUND ELEV: Hand Level 2262± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 1/5/76 — FINISHED: 1/16/76 — TOTAL DEPTH: 107.5 — BEARING: —

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 37.7' 2/2/76 (2224.3) — LOGGED BY: Taucher — LOG REVIEWED BY: —

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

1/5/76 Moved rig to DH 76-114.

Hole started 1/6/76. Nx drive samples 0 to 20.0'. 4" Cs set to 4'.

Hole at 20.0' 1/7/76. 4" Cs at 4'. Hole dry. 2-3/4" wire line core 20.0 to 30.0'. Using revert.

Hole at 30.0' 1/8/76. 4" Cs at 4'. W.L. at 10.6'. 2-3/4" wire line core 30.0 to 48.5'. Using revert.

1/9/76 Worked on equipment.

1/12/76 Worked on equipment.

Hole at 48.5' 1/13/76. 4" Cs at 4'. W.L. at 38.8'. Pulled 4" Cs. Set 6" Cs at 5'. 2-3/4" wire line core 48.5 to 63.8'. Using revert. No drill water loss.

Hole at 63.8' 1/14/76. 6" Cs at 5.0'. W.L. at 12.8'. 2-3/4" wire line core 63.8 to 83.8'. Lost sample 71.0 to 74.2' (Unable to recover). Using revert. No drill water loss.

Hole at 83.8' 1/15/76. 6" Cs at 5.0'. W.L. at 7.8'. 2-3/4" wire line core 83.8 to 107.5'. Using revert. No water loss.

Core recovery (%): 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 100, 0, 100, 100, 100

Soils analysis samples (depth, feet):

Sample	From	To
#1	1.5	41.8
#2	41.8	59.7
#3	79.8	97.2

Elevation / Depth (feet): 2260.5 / 1.5; 2220.2 / 41.8; 2202.3 / 59.7; 2182.2 / 79.8; 2164.8 / 97.2

Classification and physical condition:

0-1.5 SANDY CLAY: Dark gray, moist; organic; roots; approximately 65% low to medium plasticity fine sand and 35% fine, uniform sand; wind blow (?) (CL).

SENTINEL BUTTE FORMATION - PALEOCENE

1.5-41.8 SILTY SANDSTONE: Tan; dry; becoming moist with depth; slightly oxidized; sand is very fine grain (200 sieve); uncemented; silty; very little cohesion; crumbles easily between fingers; bedding not discernible; active HCl (caliche) reaction 1.5 to 3.0'; low plasticity clayey siltstone 13.1 to 13.4'.

41.8-59.7 SILTY SHALE: Light gray; moist; moderately soft to moderately firm; cuts easily with knife; moderately plastic; bedding not generally discernible; air slakes; scattered ¼" to ½" marcasite nodules; ¼" lignite along 35° bedding plane at 42.5'; several thin (1/16") carbonaceous streaks dipping at 30° 47.5 to 48.5'; 1" lignite inclusion at 51.5'; ½" dark gray carbonaceous streak (dip 30°) at 53.0'; lignite 54.5 to 54.8'; 2" dark gray lignitic shale (dip 20°) at 57.3'; 3/8" lignite (dip 20°) at 57.5'; dark gray lignitic shale (dip 15°) 59.0 to 59.5'; alternating silty shale and clayey siltstone 55.0 to 57.0'; laminated 57.5 to 59.7'; core lengths 6 to 18".

59.7-79.8 LIGNITE: Banded dark brown and black; moist to wet; broken and moderately soft 59.7 to 67.0'; hard below 67.0'; core lengths 1 to 8".

79.8-97.2 SHALE: Medium gray; moist; moderately firm; cuts easily with knife; plastic; bedding not readily discernible above 89.3'; thin bedded below 89.3'; air slakes; carbonaceous 79.8 to 80.0'; 60° slickenside at 85.8'; broken lignite 87.1 to 88.0' (top contact is 20° slickenside); dark gray, banded lignitic shale with ½" lignite streaks 89.3 to 89.9'; light gray, banded, fine grain sandstone 93.8 to 94.1'; core lengths 6 to 18".

97.2-107.5 SHALEY SANDSTONE AND SANDSTONE: Alternating light and

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: N. Dakota — SHEET 1 OF 2 — HOLE NO. DH 76-114

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: North Dakota

HOLE NO. DH 76-114 — LOCATION: 2500' S. of NW Corner Sec. 11, T. 144 N., R. 94 W. — GROUND ELEV: Hand Level 2262± — DIP (ANGLE FROM HORIZ.): Vertical

BEGUN: 1/5/76 — FINISHED: 1/16/76 — TOTAL DEPTH: 107.5 — BEARING: —

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 37.7' 2/2/76 (2224.3) — LOGGED BY: Taucher — LOG REVIEWED BY: —

Notes on water losses and levels, casing, cementing, caving, and other drilling conditions:

1/16/76 Pulled 6" Cs. Moved drill rig. W.L. at 3.8'. Hole completed.

2/2/76 W.L. at 37.7'. Backfilled hole with pea gravel.

5 pound lignite samples taken at the following intervals:
62.0 to 65.0'
68.0 to 71.0'
74.2 to 76.8'

Core recovery (%): 100

Soils analysis samples (depth, feet):

Sample	From	To
#4	97.2	107.5

Elevation / Depth (feet): 2154.5 / 107.5

Classification and physical condition:

medium gray laminations; top is shaley sandstone or sandy shale (low plasticity) grading to sandstone with depth; sand is very fine grain, uncemented; crumbles between fingers with some difficulty; laminations dip about 20° 97.2 to 99.5' and are horizontal below 99.5'; scattered ¼ to ½" marcasite nodules especially in lower more sandy half; core lengths 3 to 12".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole: D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed: P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series): Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series): Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series): Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series): Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: N. Dakota — SHEET 2 OF 2 — HOLE NO. DH 76-114

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

GEOLOGIC LOGS OF DH 75-113 & 76-114

GEOLOGY: G. TAUCHER — SUBMITTED: —
DRAWN: — RECOMMENDED: —
CHECKED: — APPROVED: —

BILLINGS, MONT. — MAY 1976 — 1305-600-92

7-1337 (8-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 1

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: North Dakota
HOLE NO. DH75-115 — LOCATION: 2550' N. & 2580' W. of SE Corner, Section 11, T. 144 N., R. 94 W. — GROUND ELEV. 2230± (Hand Level) — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN 12/16/75 — FINISHED 12/18/75 — TOTAL DEPTH 50.0 — BEARING —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 22.6' 1/7/76 (2207.4) — LOGGED BY: Taucher — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started 12/16/75. Nx drive samples 0 to 28.5'.

Hole at 28.5' 12/17/75. Hole caved at 12'. Cold weather (-25°) hampered drilling operations. Reamed hole to 28.5'. Set Nx Cs to 27.0'. Nx drive samples 28.5 to 30.0'.

Hole at 30.0' 12/18/75. Nx Cs at 27.0'. W.L. at 22.2'. Nx core 30.0 to 50.0'. Nx Cs advanced to 30.0'. Pulled Nx Cs hole completed.

1/7/76. W.L. at 22.6'. (2207.4)
2/2/76 W.L. at 22.9' (2207.1). Hole backfilled with pea gravel.

No lignite samples.

Core recovery (%): 75, 100, 100, 100, 100, 100, 100, 100, 96

Soils analysis sample: No soils analysis samples taken.

Elevation (feet)	Depth (feet)
2229.0	1.0
2222.0	8.0
2203.5	26.5
2202.0	28.0
2189.7	40.3
2180.0	50.0

CLASSIFICATION AND PHYSICAL CONDITION

0-1.0 SILTY CLAY: Black; moist; organic; few roots; approximately 60% low plasticity fines and 40% fine, uniform sand (CL-ML).

1.0-8.0 CLAY: Brown; moist; soft; approximately 65% low to medium plasticity fines and 35% fine, uniform sand; numerous, small (1/8") red, clinker fragments, very slight acid reaction.

SENTINEL BUTTE FORMATION - PALEOCENE
8.0-26.5 CLINKER: Red; damp; angular fragments of hard, baked shale; pulverized to dust in places by drilling.

26.5-28.0 LIGNITE: Black; wet; soft; shattered.

28.0-40.3 SHALE: Medium gray and highly plastic 28.0 to 33.2 and 36.3 to 40.3'; light gray, silty and moderately plastic 33.2 to 36.3'; moist; firm; difficult trimming by knife; air slakes; bedding not readily discernible; slightly oxidized 28.0 to 30.0'; core lengths 6 to 24".

40.3-50.0 SILTY SANDSTONE AND SANDSTONE: 40.3-46.5 alternating laminations of light and medium gray, silty, fine grain, uncemented sandstone; few carbonaceous streaks 41.5 to 42.3'; crumbles easily between fingers. 46.5-50.0 light gray, fine grain, uncemented sandstone; crumbles easily between fingers.

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, N = Neystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series). Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field ... PROJECT EMRIA No. 9 .. STATE N. Dakota . SHEET 1 OF 1 .. HOLE NO. DH75-115

7-1337 (8-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 1

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: North Dakota
HOLE NO. DH76-116 — LOCATION: 1000' S. of Center Section 10, T. 144 N., R. 94 W. — GROUND ELEV. 2227± (Hand Level) — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN 1/22/76 — FINISHED 1/23/76 — TOTAL DEPTH 49.0 — BEARING —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 6.3' 2/2/76 (2220.7) — LOGGED BY: Taucher — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started 1/22/76. Set up drill rig. Nx drive samples 0 to 10.0'. Nx rotation 10.0 to 27.4'. 2-3/4" wire line core 27.4 to 49.0'. 6" Cs set to 5'. Using revert. No drill water loss.

1/23/76 Pulled 6" Cs. Moved rig to DH76-111. Hole completed at 49.0'.

2/2/76 W.L. at 6.3' (2220.7). Hole backfilled with pea gravel.

5 pound lignite samples taken at the following intervals:

27.4 to 30.2'
33.4 to 36.4'

Core recovery (%): 100, 100, 100, 92, 100, 100, 100, 100, 100

Soils analysis sample	From	To
#1	0	5.0
#2	5.0	27.0
#3	37.2	49.0

Elevation (feet)	Depth (feet)
2222.0	5.0
2200.0	27.0
2189.8	37.2
2178.0	49.0

CLASSIFICATION AND PHYSICAL CONDITION

0-5.0 SILTY SAND: Dark gray and organic with roots 0 to 1.5'; tan to gray 1.5 to 5.0'; dry; approximately 15% nonplastic fines and 85% fine, uniform sand; top 1' contains about 25% very low plasticity fines; slightly calcareous 4.5 to 5.0'; wind blown (SM).

5.0-27.0 SANDY CLAY: Brown; oxidized; dry 5.0 to 10.0'; moist below 10.0'; soft; approximately 35% mostly fine sand, 60% medium plasticity fines and 5% fine, subrounded, hard gravel (maximum size 3/4"); active HCl reaction 5.0 to 10.5'; slight to moderate HCl reaction below 10.5'; numerous lignite inclusions; glacial till.

SENTINEL BUTTE FORMATION - PALEOCENE
27.0-37.2 LIGNITE: Banded black to dark brown; moist to wet; soft and broken 27.0 to 28.0 and 32.0 to 37.2'; remaining core in 2 to 12" lengths.

37.2-49.0 SILTY SHALE WITH LIGNITE: Medium gray with dark gray carbonaceous zones; moderately soft; cuts easily with knife; moist to wet; moderately plastic; bedding not readily discernible; air slakes; lignitic with ½" lignite bed (20° dip) 37.2 to 37.5'; hard lignite 38.3 to 38.9'; irregular 60 to 70° slickensides 38.9 to 39.3'; ½" lignite at 39.3'; core lengths 1 to 12".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, N = Neystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series). Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field ... PROJECT EMRIA No. 9 .. STATE N. Dakota . SHEET 1 OF 1 .. HOLE NO. DH76-116

7-1337 (8-69)
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 1

FEATURE: Horse Nose Butte Study Site, Dunn Center Lignite Field — PROJECT: EMRIA No. 9 — STATE: North Dakota
HOLE NO. DH76-117 — LOCATION: 2550' N. of SW Corner Sec. 3, T. 144 N., R. 94 W. — GROUND ELEV. 2180± — DIP (ANGLE FROM HORIZ.): Vertical
BEGUN 2/4/76 — FINISHED 2/4/76 — TOTAL DEPTH 40.3 — BEARING —
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED: 2.2' 2/9/76 (2177.8) — LOGGED BY: Taucher — LOG REVIEWED BY:

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started and completed 2/4/76. Nx drive samples 0 to 12.6'. Set NxCs to 12.5'. Nx core 12.6 to 40.3'. No drill water loss below 12.5'. Pulled NxCs.

2/9/76 W.L. at 2.2'. (2177.8)

2/18/76 W.L. at ground surface. 2180±. Water from melting snow may have filled hole. Backfilled hole with pea gravel.

5 pound lignite samples taken at the following intervals:

12.6 to 15.4'
19.6 to 22.6'
24.3 to 26.6'
33.9 to 35.5'

Core recovery (%): 100, 77, 56, 100, 100, 100

Soils analysis sample	From	To
#1	1.4	10.9
#2	31.7	40.3 minus lignite

Elevation (feet)	Depth (feet)
2178.6	1.4
2169.1	10.9
2152.7	27.3
2151.8	28.2
2148.3	31.7
2139.1	40.3

CLASSIFICATION AND PHYSICAL CONDITION

0-1.4 SILTY SAND: Dark gray; moist; roots; organic; approximately 25% low plasticity fines and 75% fine, uniform sand (SM).

SENTINEL BUTTE FORMATION - PALEOCENE
1.4-10.9 SILTY SANDSTONE: Tan; oxidized; moist to wet; soft; cuts easily with knife; crumbles easily between fingers; sand is fine grain and uniform; contains about 25% non to slight plasticity fines; silty clay 1.4 to 2.0 and 10.0 to 10.9'; core lengths 1 to 3".

10.9-27.3 LIGNITE: Black; moist to wet; soft and broken 10.9 to 16.6'; plastic, soft, lignitic shale 26.7 to 26.9'; core lengths 1 to 6" below 16.6'.

27.3-28.2 SHALE: Dark gray; moist; lignitic; moderately soft; cuts easily with knife; numerous slickensides; plastic; 2" lignite inclusion surrounded by slickensides 27.6 to 27.8'; 1 to 2" core lengths.

28.2-31.7 SANDSTONE: Light gray; moist to wet; fine grain; approximately 10% nonplastic fines; fair cohesion, uncemented; crumbles between fingers; 1" lignite fragment surrounded by a cluster of marcasite crystals 29.0 to 29.2'; bedding not readily discernible; core lengths 1 to 6".

31.7-40.3 SHALE: Medium gray; moist; moderately soft; cuts easily with knife; laminated in places; several 1/8" lignite streaks 31.7 to 32.5'; banded lignitic shale (dip 10°) 33.3 to 33.7' and 35.7 to 35.8'; lignite 33.7 to 35.7'; 60° joint at 39.5'; air slakes; core lengths 2 to 12".

EXPLANATION

CORE LOSS / CORE RECOVERY

Type of hole .... D = Diamond, N = Neystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series). Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field ... PROJECT EMRIA No. 9 .. STATE N. Dakota . SHEET 1 OF 1 .. HOLE NO. DH76-117

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

GEOLOGIC LOGS OF 75-115, 76-116 AND DH 75-117

GEOLOGY: G. TAUCHER — SUBMITTED:
DRAWN: — RECOMMENDED:
CHECKED: — APPROVED:
BILLINGS, MONT. — MAY 1976 — 1305-600-93

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 1

FEATURE	Horse Nose Butte Study Site, Dunn Center Lignite Field
PROJECT	EMRIA No. 9
STATE	North Dakota
HOLE NO.	DH76-118
LOCATION	900' N & 800' W. of SE Corner, Sec. 3, T. 144 N., R. 94 W.
GROUND ELEV.	Hand Level 2203±
DIP (ANGLE FROM HORIZ.)	Vertical
BEGUN	1/30/76
FINISHED	2/3/76
TOTAL DEPTH	58.4
BEARING	—
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED	39.9 2/18/76 (2163.1')
LOGGED BY	Teucher
LOG REVIEWED BY	

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started 1/30/76. Nx drive samples 0 to 6.0 and 6.6 to 10.0'. Nx core 6.0 to 6.6' and 10.0 to 15.0'. 6" Cs set to 5.0'.

Hole at 15.0' 2/3/76. 6" Cs at 5.0'. Hole dry. 2-3/4" wire line core 15.0 to 58.4'. Using revert. Dropped core and recovered in redrill 25.6 to 29.5'. 50 g.p.m. water loss 46.0 to 58.4'. Hole completed at 58.4'.

2/9/76 W.L. at 39.8' (2163.2). 2/18/76 W. L. at 39.9' (2163.1). Backfilled hole with pea gravel.

5 pound lignite samples taken at the following intervals:

30.0 to 33.0'
37.0 to 39.3'
41.5 to 43.0'
44.0 to 46.5'

CORE RECOVERY (%): 100, 100, 100, 77, 100, 100, 100, 100

SOIL ANALYSIS SAMPLE – DEPTH (FEET):

No.	From	To
#1	1.1	21.5
#2	47.7	58.4 minus lignite

ELEVATION (FEET)	DEPTH (FEET)
2201.9	1.1
2181.5	21.5
2173.5	29.5
2155.3	47.7
2144.6	58.4

Samples for testing: F, G

CLASSIFICATION AND PHYSICAL CONDITION

0-1.1 SILTY CLAY: Dark grey; moist; organic; roots; approximately 35% fine, uniform sand and 65% medium plasticity fines (CL)

SENTINEL BUTTE FORMATION - PALEOCENE

1.1-21.5 CLAYEY SILTSTONE TO SILTY SHALE: Tan becoming light grey with depth; oxidized with oxidation decreasing with depth; dry becoming moist below 7.0'; laminated; low plasticity clayey siltstone 1.1 to 10.0' with hard, cemented limestone 6.0 to 7.0'; moderately plastic silty shale 10.0 to 21.5'; trims easily with knife; active HCl reaction 1.1 to 3.0 and 5.0 to 7.0'; 1" lignite at 11.5'; highly oxidized around sandstone streak 13.5 to 13.8'; air slakes below 10.0'; core lengths 1 to 12".

21.5-29.5 SHALE, LIGNITIC SHALE & LIGNITE: Medium to dark grey plastic shale with carbonaceous or lignitic zones; moist; 21.5-24.9 - medium grey, slightly carbonaceous shale with black lignitic shale 22.2 to 23.0 and 23.5 to 24.0'; badly broken; 70° joint 23.0 to 23.5'; trims easily by knife.
24.9-25.6 - soft, black lignite
25.6-29.5 - soft, plastic medium grey shale; air slakes

29.5-47.7 LIGNITE: Banded black and dark brown; moist to wet; soft and badly broken 29.5 to 35.0'; remaining core 1 to 6" lengths.

47.7-58.4 SHALE WITH LIGNITE: Medium to dark grey; moist; moderately firm; cuts by knife with some difficulty; plastic; air slakes; bedding not readily discernible; dark grey lignitic shale 47.7 to 48.7'; ½" marcasite nodule at 48.8'; hard lignite 53.4 to 54.3' and 54.4 to 55.0'; laminated light grey silty shale 55.0 to 58.4'; core lengths 3 to 12".

EXPLANATION: CORE LOSS; CORE RECOVERY

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field PROJECT EMRIA No. 9 STATE N. Dakota SHEET 1 OF 1 HOLE NO. DH76-118

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 1

FEATURE	Horse Nose Butte Study Site, Dunn Center Lignite Field
PROJECT	EMRIA No. 9
STATE	North Dakota
HOLE NO.	DH76-119
LOCATION	2170' E of N.W. Corner, Sec. 11 T. 144 N., R. 94 W.
GROUND ELEV.	Hand Level 2186'
DIP (ANGLE FROM HORIZ.)	Vertical
BEGUN	2/5/76
FINISHED	2/5/76
TOTAL DEPTH	12.7
BEARING	—
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED	2.9' 2/9/76 (2183.1)
LOGGED BY	Teucher
LOG REVIEWED BY	

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started and completed 2/5/76. Nx drive samples 0 to 12.7'.

2/9/76 W. L. at 2.9' (2183.1). Hole backfilled with pea gravel.

Hole drilled at edge of roadway.

CORE RECOVERY (%): 100, 70, 42, 100

No samples taken.

ELEVATION (FEET)	DEPTH (FEET)
2182.5	3.5
2179.6	6.4
2176.0	10
2173.3	12.7

Samples for testing: G

CLASSIFICATION AND PHYSICAL CONDITION

0-3.5 CLAYEY SAND: Brown; moist; approximately 30% low to medium plasticity fines, 50% mostly fine sand and 20% angular clinker gravels; mostly roadfill (SC).

3.5-6.4 SANDY CLAY: Brown; moist; oxidized; approximately 35% mostly fine sand, 15% angular clinker gravels and 50% medium plasticity fines; caliche 3.5 to 4.0'.

SENTINEL BUTTE FORMATION - PALEOCENE

6.4-10.0 SHALE: Medium to dark grey; moist; lignitic in places; plastic; trims easily with knife; air slakes; core lengths 1 to 3".

10.0-12.7 LIGNITE: Black; moist; becoming too firm to drive sample.

Note: Base of Dunn Center clinker is exposed immediately west of DH76-119 at about elevation 2186±.

EXPLANATION: CORE LOSS; CORE RECOVERY

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field PROJECT EMRIA No. 9 STATE N. Dakota SHEET 1 OF 1 HOLE NO. DH76-119

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 1

FEATURE	Horse Nose Butte Study Site, Dunn Center Lignite Field
PROJECT	EMRIA No. 9
STATE	North Dakota
HOLE NO.	DH76-120
LOCATION	60' E of N.W. Corner, Sec. 12, T. 144 N., R 94 W.
GROUND ELEV.	Hand Level 2193
DIP (ANGLE FROM HORIZ.)	Vertical
BEGUN	2/5/76
FINISHED	2/5/76
TOTAL DEPTH	16.0
BEARING	—
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED	Dry 2/9/76
LOGGED BY	Teucher
LOG REVIEWED BY	

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started and completed 2/5/76. Nx drive samples 0 to 16.0'. Unable to drive sample below 16.0'.

2/9/76 Hole dry. Backfilled with pea gravel.

Hole drilled at edge of roadway.

CORE RECOVERY (%): 100, 100, 100

No samples taken.

ELEVATION (FEET)	DEPTH (FEET)
2191.0	2.0
2188.0	5.0
2177.0	16.0

CLASSIFICATION AND PHYSICAL CONDITION

0-2.0 CLAYEY SAND: Brown; moist; soft; approximately 20% low plasticity fines and 80% fine, uniform sand (SC) to (SC-SM); roadfill.

2.0-5.0 CLAYEY SAND: Medium grey and slightly organic 2.0 to 3.2'; tan and oxidized 3.2 to 5.0'; approximately 30% low to medium plasticity fines and 70% fine, uniform sand (SC).

SENTINEL BUTTE FORMATION - PALEOCENE

5.0 to 16.0 CLAYEY SANDSTONE: Tan; oxidized; moist; laminated; soft; cuts neatly with knife; contains about 25% moderately plastic fines; sand is fine and uniform; contains less fines (10%) 10.0 to 16.0'; core lengths 1 to 6".

EXPLANATION: CORE LOSS; CORE RECOVERY

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field PROJECT EMRIA No. 9 STATE N. Dakota SHEET 1 OF 1 HOLE NO. DH76-120

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 1

FEATURE	Horse Nose Butte Study Site, Dunn Center Lignite Field
PROJECT	EMRIA No. 9
STATE	North Dakota
HOLE NO.	DH76-121
LOCATION	50' N. of S.E. Corner, Sec. 1, T 144 N., R. 94 W.
GROUND ELEV.	Hand Level 2188±
DIP (ANGLE FROM HORIZ.)	Vertical
BEGUN	2/6/76
FINISHED	2/6/76
TOTAL DEPTH	8.5
BEARING	—
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED	Dry 2/9/76
LOGGED BY	Teucher
LOG REVIEWED BY	

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Hole started and completed 2/6/76. Nx drive samples 0 to 8.5'.

2/9/76 Hole dry. Backfilled with pea gravel.

Hole drilled at edge of roadway.

CORE RECOVERY (%): 100, 100

No samples taken.

ELEVATION (FEET)	DEPTH (FEET)
2183.0	5.0
2179.5	8.5

Samples for testing: G?

CLASSIFICATION AND PHYSICAL CONDITION

0-5.0 SANDY CLAY: Brown, dry to moist; soft; approximately 35% fine, uniform sand and 65% medium plasticity fines; upper 3' is fill; lower 2' is reworked shale; contains clinker fragments; active HCl reaction.

SENTINEL BUTTE FORMATION - PALEOCENE

5.0-8.5 SHALE: Medium to dark grey; moist; plastic; soft; cuts easily with knife; laminated in zones; lignite 6.0 to 6.3'; lignitic shale 7.2 to 7.6'; core lengths 1 to 6".

Note: Base of Dunn Center clinker is exposed immediately north of DH76-121 at about elevation 2190±.

EXPLANATION: CORE LOSS; CORE RECOVERY

FEATURE Horse Nose Butte Study Site, Dunn Center Lignite Field PROJECT EMRIA No. 9 STATE N. Dakota SHEET 1 OF 1 HOLE NO. DH76-121

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

GEOLOGIC LOGS OF DH 76-118 THROUGH-121

GEOLOGY R. TEUCHER .... SUBMITTED ....
DRAWN .... RECOMMENDED ....
CHECKED .... APPROVED ....

BILLINGS, MONT. MAY 1978 | 1305-600-94

APPENDIX B

COAL RESOURCES

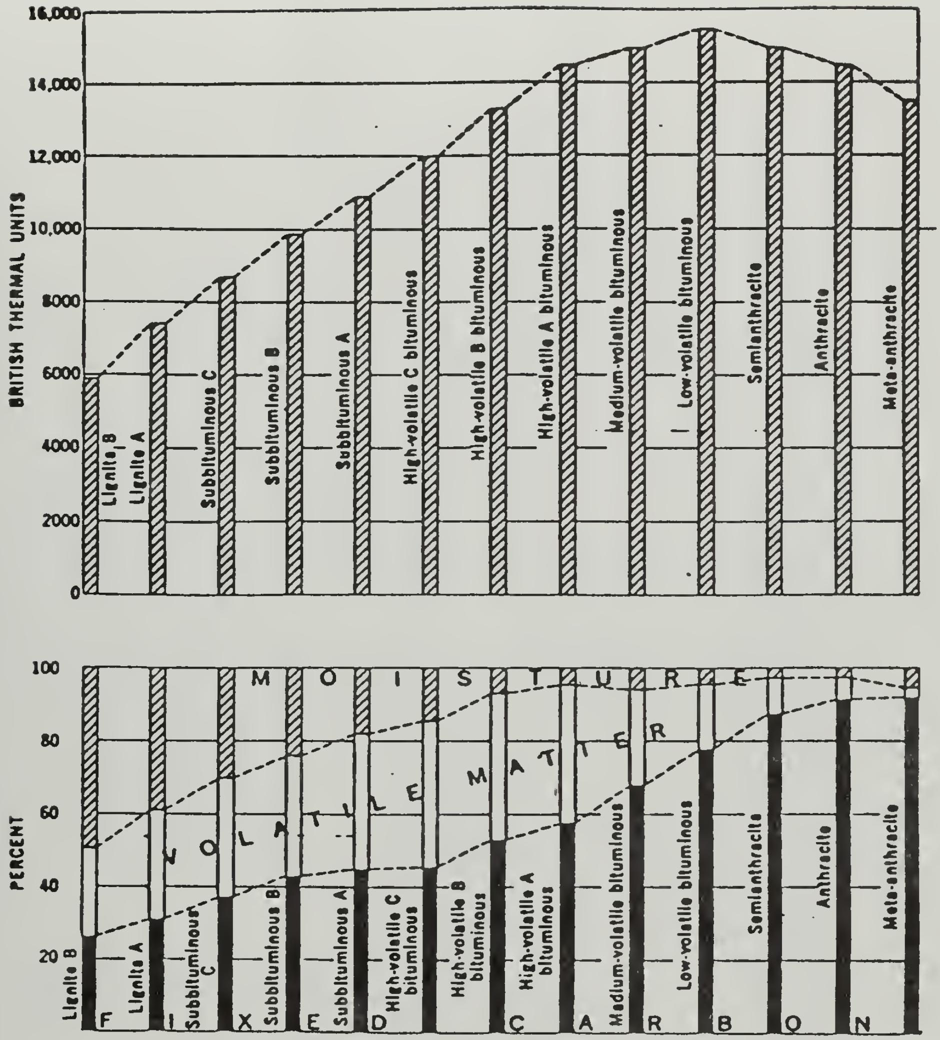


Figure 3--Comparison on moist, mineral-matter-free basis of heat values and proximate analyses of coal of different ranks.

Figure 4.--Sequence of sample preparation and chemical analysis.

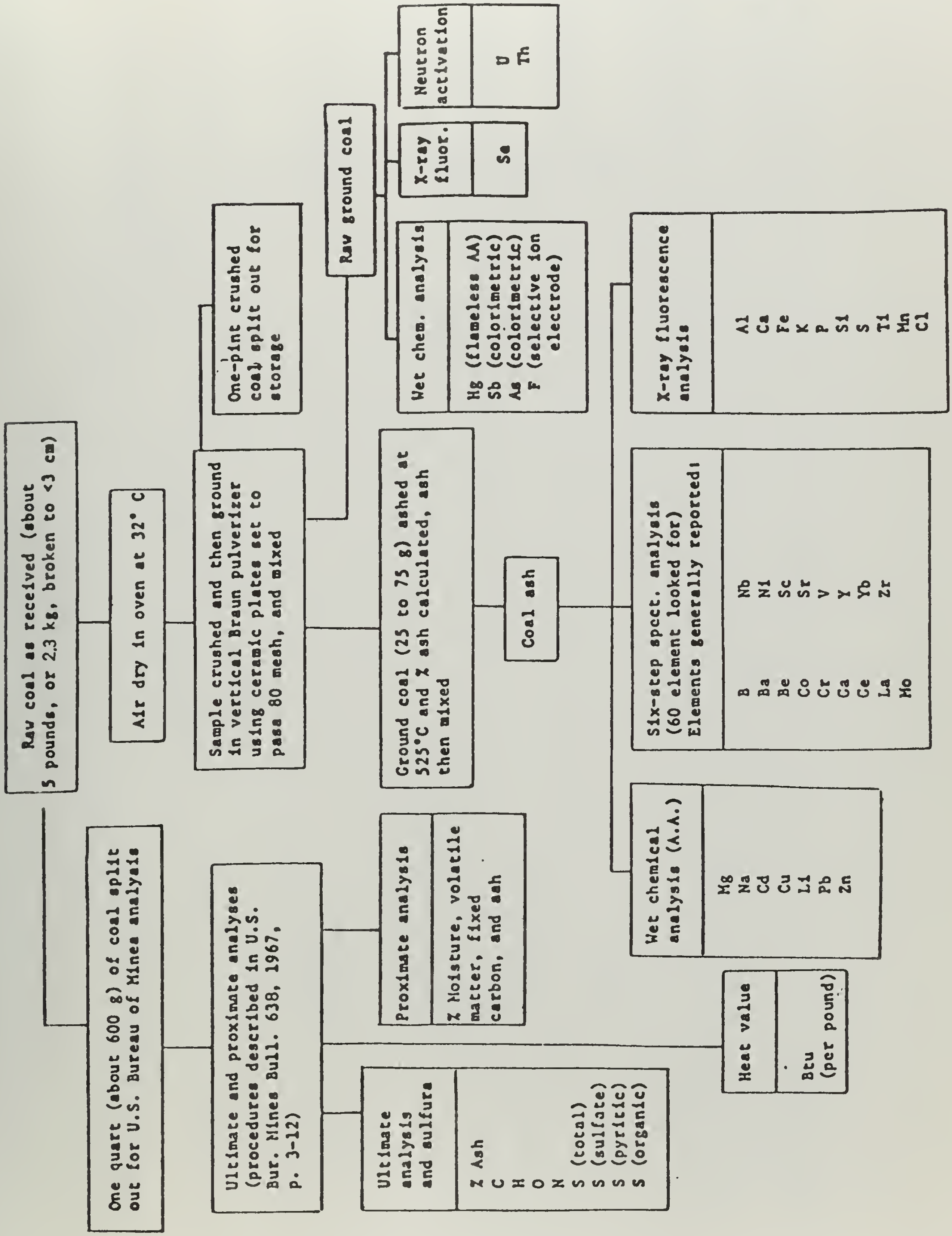


Table 2 **Classification of coals by rank**[1]
[American Society for Testing and Materials Standard D388-66 (Reapproved 1972)]

Class	Group	Fixed Carbon Limits, percent (Dry, Mineral-Matter-Free Basis)		Volatile Matter Limits, percent (Dry, Mineral, Matter-Free Basis)		Calorific Value Limits, Btu per pound (Moist,[2] Mineral-Matter-Free Basis)		Agglomerating Character
		Equal or Greater Than	Less Than	Greater Than	Equal or Less Than	Equal or Greater Than	Less Than	
I. Anthracite	1. Meta-anthracite	98	...	...	2	...	...	nonagglomerating
	2. Anthracite	92	98	2	8	...	...	nonagglomerating
	3. Semianthracite[3]	86	92	8	14	...	...	nonagglomerating
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	...	...	Commonly agglomerating[5]
	2. Medium volatile bituminous coal	69	78	22	31	...	...	Commonly agglomerating[5]
	3. High volatile A bituminous coal	...	69	31	...	14 000[4]	...	Commonly agglomerating[5]
	4. High volatile B bituminous coal	...	...	...	...	13 000[4]	14 000	Commonly agglomerating[5]
	5. High volatile C bituminous coal	...	...	...	...	11 500	13 000	Commonly agglomerating[5]
						10 500	11 500	agglomerating
III. Subbituminous	1. Subbituminous A coal	...	...	...	...	10 500	11 500	nonagglomerating
	2. Subbituminous B coal	...	...	...	...	9 500	10 500	nonagglomerating
	3. Subbituminous C coal	...	...	...	...	8 300	9 500	nonagglomerating
IV. Lignitic	1. Lignite A	...	...	...	...	6 300	8 300	nonagglomerating
	2. Lignite B					...	6 300	nonagglomerating

[1]This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free British thermal units per pound.

[2]Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

[3]If agglomerating, classify in low-volatile group of the bituminous class.

[4]Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of calorific value.

[5]It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and there are notable exceptions in high volatile C bituminous group.

Table 3--Proximate analysis of specimen sample, as received, percent

County	Kind of sample	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Calorific value of sample, as received Btu per pound
Billings	Delivered	38.0	25.8	29.4	6.8	0.6	7,010
Burleigh	do	31.9	30.2	31.8	6.1	.6	7,530
Divide	do	32.9	26.5	33.2	7.4	.5	7,590
McKenzie	do	41.9	24.2	28.4	5.5	.5	6,400
McLean	Mined	38.0	26.7	29.7	5.6	.4	6,710
Mercer	Delivered	32.9	26.4	33.3	7.4	.8	7,320
Morton	Mined	35.6	28.9	27.9	7.6	1.4	7,020
Ward	Delivered	35.1	26.5	30.0	8.4	.3	6,720
Williams	Mined	41.4	24.6	28.1	5.9	.9	6,600
Average		36.4	26.6	30.2	6.7	.7	6,990

Table 4.—Proximate, ultimate, Btu, and forms of sulfur analyses of seven lignite samples from North Dakota

[All analyses except Btu are in percent. Original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination. Form of analysis: 1, as received; 2, moisture free; 3, moisture and ash free. All analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pa. Sample D173466* is a composite of samples D173466 and D173467; D173468* is a composite of D173468 and D173469; D175930* is a composite of samples D175930 and D175931; D175932* is a composite of samples D175932 and D175933; D175934* is a composite of samples D175934 and D175935; D175936* is a composite of samples D175936 and D175937; D175938* is a composite of samples D175938 and D175939]

		PROXIMATE ANALYSIS				ULTIMATE ANALYSIS				
SAMPLE	FORM OF ANALYSIS	MOISTURE	VOL.MTR.	FIXED C	ASH	HYDROGEN	CARBON	NITROGEN	OXYGEN	SULFUR
D173466*	1	23.1	32.5	28.6	15.8	5.5	41.9	0.6	31.3	4.9
	2	-	42.2	37.3	20.5	3.9	54.4	.8	14.1	6.3
	3	-	53.1	46.9	-	4.9	68.5	1.0	17.7	7.9
D173468*	1	36.9	27.1	25.1	10.9	6.7	37.0	.5	41.8	3.1
	2	-	43.0	39.6	17.4	4.1	58.6	.8	14.2	4.9
	3	-	52.0	48.0	-	5.0	70.9	1.0	17.2	5.9
D175930*	1	27.5	30.0	36.3	6.2	6.1	46.7	.7	39.9	.4
	2	-	41.3	50.2	8.5	4.2	64.4	1.0	21.3	.6
	3	-	45.2	54.8	-	4.6	70.5	1.0	23.3	.6
D175932*	1	27.5	28.6	35.6	8.3	6.0	45.3	.6	39.5	.3
	2	-	39.5	49.1	11.4	4.0	62.5	.9	20.7	.5
	3	-	44.5	55.5	-	4.5	70.5	1.0	23.5	.5
D175934*	1	30.0	29.3	35.4	5.3	6.2	45.2	.7	42.4	.2
	2	-	41.9	50.5	7.6	4.1	64.6	.9	22.5	.3
	3	-	45.3	54.7	-	4.4	69.9	1.0	24.3	.4
D175936*	1	27.7	30.6	33.5	8.2	6.1	45.6	.7	38.2	1.2
	2	-	42.4	46.3	11.3	4.2	63.0	.9	18.9	1.7
	3	-	47.8	52.2	-	4.8	71.7	1.0	21.2	1.9
D175938*	1	35.2	28.8	30.2	5.8	6.4	40.1	.8	46.6	.3
	2	-	44.4	46.6	9.0	3.9	61.9	1.0	23.7	.5
	3	-	48.7	51.3	-	4.2	68.0	1.1	26.1	.6

Table 4.--Proximate, ultimate, Btu, and forms of sulfur analyses of seven lignite samples from North Dakota--Continued

SAMPLE	ANALYSIS	BTU	A.D.LOSS	FORMS OF SULFUR		
				SULFATE	PYRITIC	ORGANIC
D173466*	1	7210	5.79	0.08	4.13	0.64
	2	9360	-	.11	5.36	.83
	3	11780	-	.14	6.75	1.05
D173468*	1	6330	26.56	.04	2.58	.46
	2	10040	-	.07	4.09	.73
	3	12150	-	.08	4.94	.89
D175930*	1	7700	15.20	.02	.04	.37
	2	10610	-	.02	.06	.52
	3	11600	-	.02	.06	.56
D175932*	1	7410	14.60	.02	.04	.28
	2	10220	-	.02	.06	.39
	3	11530	-	.03	.06	.44
D175934*	1	7510	18.30	.03	.01	.20
	2.	10730	-	.05	.01	.28
	3	11610	-	.05	.01	.31
D175936*	1	7630	13.90	.13	.79	.33
	2	10540	-	.17	1.09	.45
	3	11900	-	.20	1.23	.51
D175938*	1	6400	22.60	.07	.01	.24
	2	9870	-	.11	.02	.38
	3	10840	-	.13	.03	.41

Table 5.--Description of seven samples from the Sentinel Butte Member in Stark and Mercer Counties. (Collected by C. G. Carlson, North Dakota Geological Survey.)

Sample	County	Location	Bed	Thickness
D173466	Stark	Sec. 17, T. 139 N., R. 95 W.	Lehigh	8
D173468	do	do	do	8
D175930	Mercer	Sec. 36, T. 144 N., R. 89 W.	Beulah-Zap	10.5
D175932	do	do	do	10.5
D175934	do	do	do	10
D175936	do	do	do	8
D175938	do	Sec. 31, T. 144 N., R. 88 W.	do	8

Table 8.--Major and minor oxide and trace-element composition of the laboratory ash of 14 lignite samples from the Fort Union Region, N. Dak.

[Values are in either percent or parts per million. The lignites were ashed at 525°C. L after a value means less than the value shown, N means not detected, and B means not determined. S after the element title means that the values listed were determined by semiquantitative spectrographic analysis. The spectrographic results are to be identified with geometric brackets whose boundaries are 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, etc., but are reported arbitrarily as mid-points of those brackets, 1.0, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, etc. The precision of the spectrographic data is approximately one bracket at 68-percent, or two brackets at 95-percent confidence]

SAMPLE	ASH %	SIO2 %	AL2O3 %	CAO %	MGO %	NA2O %	K2O %	FE2O3 %	MNO %	TIO2 %
D173466	25.6	5.0	3.4	6.3	2.22	0.88	0.073	50.	0.059	0.088
D173467	12.2	37.	9.3	17.	6.09	3.86	.13	.29	.073	1.0
D173468	19.6	18.	6.0	9.7	3.47	1.90	.32	24.	.036	.39
D173469	11.0	8.5	6.6	15.	5.25	4.71	.064	17.	.061	.24
D175930	11.7	10.	4.7	12.	4.53	7.48	.22	23.	.050L	.50
D175931	6.9	17.	9.1	23.	8.07	9.88	.20	5.6	.050L	.64
D175932	12.1	47.	10.	15.	4.96	4.93	.22	3.5	.050L	1.1
D175933	5.6	11.	6.9	24.	8.53	11.7	.28	6.5	.050L	.47
D175934	5.5	11.	6.2	27.	9.63	11.2	.24	5.4	.050L	.36
D175935	7.3	27.	9.0	16.	6.13	12.4	.46	4.8	.050L	.95
D175936	9.6	14.	6.1	20.	6.18	1.11	.14	16.	.050L	.64
D175937	8.4	27.	7.9	23.	7.54	1.21	.15	4.8	.050L	.94
D175938	7.3	16.	9.2	15.	6.49	9.03	.42	10.	.050L	.65
D175939	7.5	24.	9.3	18.	7.50	6.25	.43	5.8	.050L	.79

SAMPLE	P2O5 %	SO3 %	CL %	CD PPM	CU PPM	LI PPM	PB PPM	ZN PPM	AG PPM-S	B PPM-S
D173466	0.11	18.	0.10 L	1.0L	28.	13.	25.L	27.	N	300
D173467	.27	16.	.10 L	1.0L	68.	14.	25.	64.	N	1500
D173468	.15	22.	.10 L	1.0L	32.	28.	25.L	25.	N	700
D173469	.25	37.	.10 L	1.0L	44.	25.	30.	16.	1.5	1500
D175930	1.0 L	33.	.20 L	1.0L	34.	18.	25.L	22.	N	700
D175931	1.0 L	17.	.20 L	1.0L	66.	14.	40.	28.	N	700
D175932	1.0 L	6.7	.20 L	1.0L	62.	42.	25.	20.	N	1500
D175933	1.0 L	15.	.20 L	1.0L	56.	11.	30.	20.	N	1500
D175934	1.0 L	12.	.20 L	1.0L	44.	10.	25.	22.	N	1500
D175935	1.0 L	14.	.20 L	1.0L	74.	23.	25.	22.	N	1000
D175936	1.0 L	32.	.20 L	1.0L	40.	12.	25.	18.	N	1000
D175937	1.0 L	17.	.26	1.0L	74.	26.	25.	18.	N	700
D175938	1.0 L	20.	.20 L	1.0L	53.	16.	25.L	58.	N	1000
D175939	1.0 L	19.	.20 L	1.0L	66.	23.	25.	28.	N	1500

Table 8.—Major and minor oxide and trace-element composition of the laboratory ash of 14 lignite samples from the Fort Union Region, N. Dak.—Continued

SAMPLE	BA PPM-S	BE PPM-S	CO PPM-S	CR PPM-S	GA PPM-S	GE PPM-S	LA PPM-S	MO PPM-S	NB PPM-S	NI PPM-S
D173466	1500	N	N	7	B	N	N	15	20 L	20
D173467	3000	N	15	30	20	N	N	20	30	20
D173468	3000	N	10 L	15	B	N	N	7	20 L	15
D173469	3000	7	30	20	20	70	N	70	20 L	20
D175930	5000	N	10 L	10	15	N	N	10	20 L	15
D175931	5000	N	10 L	15	10	N	N	15	20 L	10
D175932	5000	N	10 L	15	30	N	100 L	10	20	20
D175933	2000	N	15	30	20	N	N	10	20 L	30
D175934	1000	N	10	15	10	N	100 L	15	20 L	50
D175935	7000	N	5	30	20	N	100 L	7	30	15
D175936	5000	N	10 L	15	10	N	N	10	20	15
D175937	5000	N	10 L	100	15	N	N	15	30	15
D175938	7000	3	10	15	15	N	100 L	10	20 L	20
D175939	5000	3	15	20	15	N	100 L	7	20 L	20

SAMPLE	SC PPM-S	SR PPM-S	V PPM-S	Y PPM-S	YB PPM-S	ZR PPM-S
D173466	N	1500	15	20 L	B	N
D173467	15	5000	50	30	3	200
D173468	10 L	2000	30	20 L	B	100
D173469	15	5000	30	50	B	70
D175930	10 L	3000	20	20	B	70
D175931	10 L	2000	20	20 L	B	50
D175932	15	5000	50	30	2	150
D175933	15	7000	30	20	2	70
D175934	10 L	7000	30	20	2	70
D175935	15	3000	50	20	2	200
D175936	10 L	2000	30	20 L	2	100
D175937	10	2000	30	30	3	200
D175938	15	3000	50	30	3	100
D175939	15	3000	50	30	2	200

Table 9 .--Content of seven trace elements in 14 lignite samples from the Fort Union Region, N. Dak.

[Analyses on air-dried (32°C) lignite. All values are in parts per million. L after a value means less than the value shown]

SAMPLE	AS PPM	F PPM	HG PPM	SB PPM	SE PPM	TH PPM	U PPM
D173466	30.	25.	0.49	1.8	2.0	4.7	0.7
D173467	2.	40.	.03	.3	.4	4.7	1.1
D173468	15.	30.	.35	.7	1.4	3.0L	.9
D173469	4.	35.	.17	1.0	.7	3.0L	2.6
D175930	12.	20.L	.37	.1	.5	3.0L	.5
D175931	2.	20.L	.04	.1	.7	3.0L	1.0
D175932	2.	20.L	.04	.1L	.6	8.0	.8
D175933	2.	20.L	.01	.1L	.4	3.0L	.5
D175934	1.	20.L	.01L	.1L	.4	3.0L	.2L
D175935	1.	20.	.03	.1	.8	3.0L	.5
D175936	15.	20.L	.12	.1	.7	3.0L	.2L
D175937	3.	20.L	.02	.1	1.0	3.0L	.8
D175938	8.	20.L	.03	.2	.6	3.0L	.2L
D175939	5.	25.	.03	.2	.7	3.0L	.5

Table 10.--Major, minor, and trace-element composition of 14 lignite samples from the Fort Union Region, N. Dak., reported on whole-lignite basis

[Values are in either percent or parts per million. Si, Al, Ca, Mg, Na, K, Fe, Mn, Ti, P, Cl, Cd, Cu, Li, Pb, and Zn values were calculated from analysis of ash. As, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32°C) lignite. The remaining analyses were calculated from spectrographic determinations on ash. L after a value means less than the value shown, N means not detected, and B means not determined]

SAMPLE	SI %	AL %	CA %	MG %	NA %	K %	FE %	MN PPM	TI %	P PPM
D173466	0.60	0.47	1.2	0.343	0.166	0.016	8.9	120.	0.014	120.
D173467	2.1	.60	1.5	.448	.349	.013	.025	69.	.074	150.
D173468	1.7	.62	1.4	.410	.276	.053	3.3	54.	.045	130.
D173469	.44	.39	1.2	.348	.384	.006	1.3	52.	.016	120.
D175930	.55	.29	1.0	.319	.648	.021	1.9	45. L	.035	510. L
D175931	.54	.33	1.1	.335	.505	.011	.27	27. L	.026	300. L
D175932	2.7	.64	1.3	.362	.442	.022	.30	47. L	.078	530. L
D175933	.30	.20	.96	.288	.486	.013	.25	22. L	.016	240. L
D175934	.28	.18	1.1	.319	.457	.011	.21	21. L	.012	240. L
D175935	.94	.35	.83	.269	.672	.028	.25	28. L	.041	320. L
D175936	.63	.31	1.4	.357	.079	.011	1.1	37. L	.037	420. L
D175937	1.1	.35	1.4	.381	.076	.010	.28	33. L	.047	370. L
D175938	.56	.35	.78	.285	.488	.026	.51	28. L	.028	320. L
D175939	.84	.37	.96	.339	.347	.027	.30	29. L	.035	330. L

SAMPLE	CL %	AS PPM	CD PPM	CU PPM	F PPM	HG PPM	LI PPM	PB PPM	SB PPM	SE PPM
D173466	0.026L	30.	0.3L	7.2	25.	0.49	3.3	6.4L	1.8	2.0
D173467	.012L	2.	.1L	8.3	40.	.03	1.8	3.1	.3	.4
D173468	.020L	15.	.2L	6.3	30.	.35	5.5	4.9L	.7	1.4
D173469	.011L	4.	.1L	4.8	35.	.17	2.8	3.3	1.0	.7
D175930	.023L	12.	.1L	4.0	20.L	.37	2.1	2.9L	.1	.5
D175931	.014L	2.	.1L	4.6	20.L	.04	1.0	2.8	.1	.7
D175932	.024L	2.	.1L	7.5	20.L	.04	5.1	3.0	.1L	.6
D175933	.011L	2.	.1L	3.1	20.L	.01	.6	1.7	.1L	.4
D175934	.011L	1.	.1L	2.4	20.L	.01L	.6	1.4	.1L	.4
D175935	.015L	1.	.1L	5.4	20.	.03	1.7	1.8	.1	.8
D175936	.019L	15.	.1L	3.8	20.L	.12	1.2	2.4	.1	.7
D175937	.022	3.	.1L	6.2	20.L	.02	2.2	2.1	.1	1.0
D175938	.015L	8.	.1L	3.9	20.L	.03	1.2	1.8L	.2	.6
D175939	.015L	5.	.1L	5.0	25.	.03	1.7	1.9	.2	.7

Table 10.--Major, minor, and trace-element composition of 14 lignite samples from the Fort Union Region, N. Dak., reported on whole-lignite basis--Continued

SAMPLE	TH PPM	U PPM	ZN PPM	AG PPM-S	B PPM-S	BA PPM-S	BE PPM-S	CO PPM-S	CR PPM-S	GA PPM-S
D173466	4.7	0.7	6.9	N	70	500	N	N	1.5	B
D173467	4.7	1.1	7.8	N	200	300	N	2	3	2
D173468	3.0L	.9	4.9	N	150	700	N	2 L	3	B
D173469	3.0L	2.6	1.8	.15	150	300	7	3	2	2
D175930	3.0L	.5	2.6	N	70	700	N	1 L	1	1.5
D175931	3.0L	1.0	1.9	N	50	300	N	.7 L	1	.7
D175932	8.0	.8	2.4	N	200	700	N	1.5 L	2	3
D175933	3.0L	.5	1.1	N	70	100	N	.7	1.5	1
D175934	3.0L	.2L	1.2	N	70	50	N	.5	.7	.5
D175935	3.0L	.5	1.6	N	70	500	N	.3	2	1.5
D175936	3.0L	.2L	1.7	N	100	500	N	1 L	1.5	1
D175937	3.0L	.8	1.5	N	70	500	N	.7 L	7	1.5
D175938	3.0L	.2L	4.2	N	70	500	.2	.7	1	1
D175939	3.0L	.5	2.1	N	100	300	.2	1	1.5	1

SAMPLE	GE PPM-S	LA PPM-S	MO PPM-S	NB PPM-S	NI PPM-S	SC PPM-S	SR PPM-S	V PPM-S	Y PPM-S	YB PPM-S
D173466	N	N	5	5 L	5	N	500	5	5 L	B
D173467	N	N	2	3	2	2	700	7	3	.3
D173468	N	N	1.5	5 L	3	2 L	500	7	5 L	B
D173469	7	N	7	2 L	2	1.5	500	3	5	B
D175930	N	N	1	2 L	1.5	1 L	300	2	2	B
D175931	N	N	1	1.5 L	.7	.7 L	150	1.5	1.5 L	B
D175932	N	15 L	1.5	2	2	2	700	7	3	.2
D175933	N	N	.5	1 L	1.5	.7	500	1.5	1	.1
D175934	N	5 L	.7	1 L	3	.5 L	500	1.5	1	.1
D175935	N	7 L	.5	2	1	1	200	3	1.5	.15
D175936	N	N	1	2	1.5	1 L	200	3	2 L	.2
D175937	N	N	1.5	2	1.5	.7	150	2	2	.2
D175938	N	7 L	.7	1.5 L	1.5	1	200	3	2	.2
D175939	N	7 L	.5	1.5 L	1.5	1	200	3	2	.15

Table 10.--Major, minor, and trace-element composition of 14 lignite samples from the Fort Union Region, N. Dak., reported on whole-lignite basis--Continued

SAMPLE	ZR PPM-S
D173466	N
D173467	20
D173468	20
D173469	7
D175930	7
D175931	3
D175932	20
D175933	5
D175934	5
D175935	15
D175936	10
D175937	15
D175938	7
D175939	15

Table 11.--Comparison of composition of Sentinel Butte Member lignite with composition of lignite from 10 mines in North Dakota and Montana

	Sentinel Butte lignite (14 samples)	Lignite from 10 mines (62 samples[1])
Btu	7,170	6,800
	In percent	
Moisture (as received)	30 (7 samples)	35
Fixed carbon (as received)	32 (7 samples)	30
Oxygen (as received)	40 (7 samples)	42
SiO_2 (in ash)	20	15
Na_2O (in ash)	6	2
CaO (in ash)	17	25
MgO (in ash)	6	8
	In parts per million	
As (whole coal)	7	5
B (whole coal)	100	150
Ba (whole coal)	425	700
Be (whole coal)	0.03 (3 samples)	0.15
Cd (whole coal)	<0.1	<0.1
Cr (whole coal)	2	3
F (whole coal)	<24	40
Hg (whole coal)	0.12	0.13
Mo (whole coal)	1.7	0.7
Ni (whole coal)	2	1.5
Pb (whole coal)	3	3
Sb (whole coal)	0.4	0.3
Se (whole coal)	0.8	0.7
Ti	360	300
U	0.8	1.1
V	4	5
Zn	3	2
Zr	10	10

[1] Swanson, V. E., and others, 1974.

Table 12.--Elements that can affect potential utilization of coals--content in 14 samples from Sentinel Butte Member, in parts per million

Element	Concentration in 14 samples: Range	Concentration in 14 samples: Average	Average, continental crust (Taylor, 1964)
As	1 - 30	7	1.8
Cd	<0.1- <0.3	<0.1	.2
Cu	2.4- 8.3	5.2	55
F	<20 - 40	<24	625
Hg	<0.01- 0.49	< 0.12	.08
Li	0.6- 5.5	2.2	20
Pb	1.4- <6.4	3	12.5
Sb	<0.1- 1.8	<0.4	.2
Se	0.4- 2.0	0.8	.05
Th	<3 - 8	<3.6	9.6
U	<0.2- 2.6	<0.8	2.7
Zn	1.1- 7.8	3	70

APPENDIX C

HYDROLOGY

Table 13

Wells and test holes

Location	Well identification	Drilled depth (in feet below land surface datum)	Top of screen (in feet below land surface datum)	Casing diameter (inches)	Date drilled (year)	Water level (in feet below land surface datum)	Date of measurment (month/year)	Altitude of land surface datum (in feet above mean sea level)
143-091-19AAA1	1/ NDSWC 4602	900	570	2	1973	119	7-74	2130
143-093-09BCB	NDSWC 4600	965	396	2	1973	93	2-74	2133
144-091-30AAA2	NDSWC 4603A	520	512	2	1974	285	9-74	2223
144-094-01CBB	2/ UND53	62	57	2	1975	17	3-76	2176
-01CBC	UND54	42	37	2	1975	14	3-76	2185
-01CCC1	UND28	660	622	2	1975	171	3-76	2190
-01CCC2	UND	--	351	2	1975	114	3-76	2190
-01CCC3	UND	--	43	2	1975	28	3-76	2190
-01CCD1	UND50	--	111	2	1975	24	3-76	2185
-01CCD2	UND	--	22	2	1975	24	3-76	2185
-01CDD1	UND49	--	91	2	1975	25	3-76	2185
-01CDD2	UND	--	52	2	1975	17	3-76	2185
-01CDD3	UND	--	21	2	1975	13	3-76	2185
-01DDD	3/ USBR76-121	8	--	-	1975	Dry	2-76	2188
-03CBB	USBR76-117	40	--	-	1976	2	2-76	2180
-03C[illegible]	4/ USGS3	55	40	4	1976	20	3-76	2200
-03DDB	USRB76-118	58	--	-	1976	40	2-76	2203
-10BAB	USBR76-111	91	--	-	1976	70	2-76	2247
-10CAD	USBR76-116	49	--	-	1976	6	2-76	2227
-10CBB	USBR76-110	81	--	-	1976	41	2-76	2251
-10DAA1	USGS1	76	70	2	1976	33	3-76	2255
-10DAA2	--	--	60	-	--	--	--	--
-11BAA	USBR76-119	13	--	-	1976	3	2-76	2186
-11BCC	USBR76-114	107	--	-	1976	38	2-76	2262
-11DBB	USBR75-115	50	--	-	1975	23	1-76	2230
-11DCC	USBR75-106	180	--	-	1975	68	11-75	2344
-12AAB1	UND51	180	168	2	1975	27	3-76	2185
-12AAB2	UND	--	122	2	1975	26	3-76	2185
-12ABA1	UND52	--	85	2	1975	27	3-76	2185
-12ABA2	UND	--	49	2	1975	27	3-76	2185
-12BBB	USBR76-120	16	--	-	1976	Dry	2-76	2193
-12BDA	USBR75-112	55	--	-	1975	17	12-75	2218
-12CBD	USBR75-107	104	--	-	1975	34	12-75	2250
-12CCC	USGS2	93	70	4	1976	52	3-76	2278
-12CDC	USBR75-108	103	--	-	1975	17	11-75	2249
-12DAD	USBR75-113	8[illegible]	--	-	1975	[illegible]3	12 75	2226
-13CBB1	UND	--	87	2	1975	68	3-76	2259
-13CBB2	UND48	70	65	2	1975	36	3-76	2255
-13CCC1	NDSWC	200	132	1	1974	113	3-76	2295
-13CCC2	UND35	66	61	2	1975	36	3-76	2295
-13CCC3	UND	--	24	2	1975	26	3-76	2295
-14ADC	USBR75-105	134	--	-	1975	25	12-75	2273
-14CCC	USBR75-103	203	--	-	1975	30	11-75	2339
-14DCC	USBR75-101	219	170	2	1975	141	3-76	2340
-15AAD	USBR75-104	133	--	-	1975	46	11-75	2281
-15BBC	USBR75-109	161	--	-	1975	121	12-75	2307
-15BDD	USBR75-102	209	174	2	1975	163	3-76	2365
-16AAA1	UND19	520	475	2	1975	186	3-76	2295
-16AAA2	UND	--	161	2	1975	104	3-76	2292
-16AAA3	UND	--	113	2	1975	99	3-76	2293
-16ABA	UND	--	73	2	1975	65	3-76	2260
-16ABB	UND	--	81	2	1975	32	3-76	2221
-23ADD1	UND18	500	--	-	1975	215	3-76	2365
-23ADD2	UND	--	201	2	1975	140	3-76	2365
-23ADD3	UND	--	65	2	1975	Dry	3-76	2365

1/ NDSWC, North Dakota State Water Commission.
2/ UND, University of North Dakota.
3/ USBR, U.S. Bureau of Reclamation.
4/ USGS, U.S. Geological Survey.

Table 14

Chemical analyses of water samples from selected wells
[Analyses are in milligrams per liter (mg/l), except as indicated]

Sample location	143-091-19AAA1	143-093-09BCB	144-091-30AAA2	144-094-01CCD1	144-094-01CDD1	144-094-10DAA2	144-094-16AAA1	144-094-23ADD2
Date of sample	04-19-74	04-24-74	07-02-74	10-22-75	10-24-75	10-29-75	10-27-75	10-29-75
Depth of well (feet)	670	396	512	114	95	60	480	198
Silica (SiO_2)	.2	8.7	9.5	--	--	--	--	--
Iron (Fe), micrograms per liter (µg/l)	40	80	40	--	--	--	--	--
Calcium (Ca)	33	4.2	17	19	38	330	120	48
Magnesium (Mg)	12	3.0	16	2.9	19	52	160	13
Sodium (Na)	660	870	610	910	600	71	480	450
Potassium (K)	7.2	4.0	7.0	9.0	8.8	5.9	52	22
Bicarbonate (HCO_3)	1,320	2,100	1,440	1,460	1,080	440	590	930
Carbonate (CO_3)	50	140	40	16	0	0	4	16
Sulfate (SO_4)	420	9.9	150	720	600	790	1,600	300
Chloride (Cl)	12	14	14	8.5	3.0	3.8	9.5	14
Fluoride (F)	.9	1.5	1.1	--	--	--	--	--
Nitrate (NO_3)	1.0	1.0	1.0	.4	.1	.6	1.6	.5
Boron (B) (µg/l)	260	40	80	--	--	--	--	--
Dissolved solids (residue at 180°C)	2,510	3,160	2,310	3,150	2,360	1,700	2,980	1,790
Hardness (Ca, Mg)	130	23	110	60	170	1,000	950	170
Noncarbonate hardness	0	0	0	0	0	330	0	0
Sodium-adsorption ratio	25	79	25	51	20	1.0	6.7	15
Percent Sodium	91	99	92	96	88	13	51	83
Specific conductance (µmhos/cm @ 25°C)	2,830	3,140	2,400	3,070	2,440	1,810	2,970	1,800
pH	8.7	8.9	8.6	8.3	8.2	6.6	8.1	8.5
Temperature (°C)	23.9	23.9	26.0	--	--	7	--	--

Chemical analyses of water samples from USGS observation wells
[Analyses are in milligrams per liter (mg/l), except as indicated]

Sample location:	144-094-03CCC	144-094-10DAA1	144-094-12CCC
Date of collection:	03-23-76	03-23-76	03-23-76
Depth of well (feet):	50.0	76.5	80.0
Alkalinity, total (as $CaCO_3$)	190	400	780
Aluminum, dissolved micrograms per liter (μg/l)	10	10	10
Arsenic, dissolved (μg/l)	0	1	1
Barium, dissolved (μg/l)	0	100	0
Beryllium, dissolved (μg/l)	0	0	0
Bicarbonate	230	490	950
Boron, dissolved (μg/l)	0	150	1
Cadmium, dissolved (μg/l)	1	1	1
Calcium, dissolved	33	26	58
Carbon, dissolved organic	2.9	19	13
Carbonate	0	0	0
Chloride, dissolved	.9	3.3	6.6
Chromium, dissolved (μg/l)	0	0	0
Cobalt, dissolved (μg/l)	0	0	0
Color	1	25	20
Copper, dissolved (μg/l)	3	7	2
Cyanide	.00	.00	.00
Fluoride, dissolved	1.0	.7	.6
Hardness, noncarbonate	38	0	0
Hardness, total	230	140	300
Iron, dissolved (μg/l)	10	20	40
Lead, dissolved (μg/l)	30	130	50
Lithium, dissolved (μg/l)	20	50	140
Magnesium, dissolved	35	19	36
Manganese, dissolved (μg/l)	10	100	200
Mercury, dissolved (μg/l)	.0	1.9	.0
Molybdenum, dissolved (μg/l)	0	2	0
Nickel, dissolved (μg/l)	0	2	2
NO_2+NO_3 as N, dissolved	.20	.07	.00
pH, field	7.5	7.4	7.5
Phosphorus, dissolved, as P	.02	.02	.08
Potassium, dissolved	.8	5.0	12
Residue, dissolved, calculated sum	247	526	3,490
Residue, dissolved, ton/acre-foot	.33	.71	4.76
Residue, dissolved @ 180°C	245	525	3,500
Sodium-adsorption ratio	[illegible]	5.5	28
Selenium, dissolved (μg/l)	0	0	0
Silica, dissolved	11	8.8	9.7
Silver, dissolved (μg/l)	0	0	0
Sodium, dissolved	5.0	150	1,100
Sodium, percent	5	69	89
Specific conductance, field (μmhos/cm @ 25°C)	410	800	4,900
Strontium, dissolved (μg/l)	250	740	2,000
Sulfate, dissolved	46	69	1,800
Vanadium, dissolved (μg/l)	.2	.6	.3
Water temperature (°C)	6.5	8.0	8.0
Zinc, dissolved (μg/l)	10	60	20

Chemical analyses of water samples: Surface-water sites
[Analyses are in milligrams per liter (mg/l), except as indicated]

Sample location:	145-093-27ABC Spring Creek nr Werner	145-093-30DDC Slow Creek nr Dunn Center	145-094-25DAD Spring Creek nr Dunn Center	145-094-26CDD Spring Creek at Dunn Center
Date of collection:	09-25-75	04-22-75	09-25-75	09-25-75
Discharge (ft^3/s)	2.2	148	1.6	1.4
Alkalinity, total (as $CaCO_3$)	400	36	460	360
Aluminum, dissolved micrograms per liter (μg/l)	20	--	--	--
Arsenic, dissolved (μg/l)	1	--	--	--
Barium, dissolved (μg/l)	<200	--	--	--
Beryllium, dissolved (μg/l)	10	--	--	--
Bicarbonate	490	44	500	440
Boron, dissolved (μg/l)	580	60	--	--
Cadmium, dissolved (μg/l)	0	--	--	--
Calcium, dissolved	69	6.7	74	62
Carbon, dissolved, organic	--	16	--	--
Carbon, organic, suspended	--	1.9	--	--
Carbonate	0	0	29	0
Chloride, dissolved	6.8	1.2	5.6	6.3
Chromium, dissolved (μg/l)	10	--	--	--
Cobalt, dissolved (μg/l)	0	--	--	--
Color	45	120	80	95
Copper, dissolved (μg/l)	4	--	--	--
Cyanide	.00	--	--	--
Fluoride, dissolved	.4	.0	.4	.4
Hardness, noncarbonate	0	0	0	0
Hardness, total	370	32	390	320
Iron, dissolved (μg/l)	30	--	60	90
Lead, dissolved (μg/l)	5	--	--	--
Lithium, dissolved (μg/l)	50	--	--	--
Magnesium, dissolved	47	3.6	50	41
Manganese, dissolved (μg/l)	40	--	80	140
Mercury, dissolved (μg/l)	.3	--	--	--
Molybdenum, dissolved (μg/l)	2	--	--	--
Nickel, dissolved (μg/l)	2	--	--	--
NO_2+NO_3 as N, dissolved	.01	--	.05	.55
pH, field	8.1	7.6	8.4	8.0
Phosphorus, dissolved as P	.02	--	.02	.04
Potassium, dissolved	9.1	5.8	9.1	11
Residue, dissolved, calculated sum	1,260	94	1,270	1,140
Residue, dissolved, ton/acre-foot	1.74	.16	1.71	1.58
Residue, dissolved ton/day	7.60	45.6	5.44	4.38
Residue, dissolved @ 180°C	1,280	114	1,260	1,160
Sodium-adsorption ratio	6.6	1.2	6.4	6.3
Selenium, dissolved (μg/l)	0	--	--	--
Silica, dissolved	10	4.7	6.6	11
Silver, dissolved (μg/l)	0	--	--	--
Sodium, dissolved	290	16	290	260
Sodium, percent	63	47	61	63
Specific conductance, field (μmhos/cm @ 25°C)	1,850	170	1,850	1,550
Strontium, dissolved (μg/l)	1,500	--	--	--
Sulfate, dissolved	580	34	560	530
Vanadium, dissolved (μg/l)	2.2	--	--	--
Water temperature (°C)	15.0	7.5	16.0	13.0
Zinc, dissolved (μg/l)	10	--	--	--

Radiochemical analyses of water samples

Sample location:	144-094-03CCC	144-094-10DAA	144-094-12CCC
Date of collection:	03-25-76	03-25-76	03-25-76
Depth of well (feet):	50	76.5	80
Gross Alpha as dissolved uranium natural micrograms per liter (μg/l)	5.6	--	52
Gross Alpha as suspended uranium natural (μg/l)	<.4	3.4	<.4
Gross Beta as dissolved CS-137 picocuries per liter (pCi/l)	1.6	7.9	13
Gross Beta as dissolved Strontium 90 (pCi/l)	1.3	6.3	11
Gross Beta as suspended CS-137 (pCi/l)	<.4	3.1	<.4
Gross Beta as suspended Strontium 90 (pCi/l)	<.4	2.4	<.4
pH, field	7.5	7.4	7.5
Potassium 40, dissolved (pCi/l)	.6	3.9	12
Residue, total filtered 105°C milligrams per liter (mg/l)	260	560	3,700
Residue, total nonfiltered 105°C (mg/l)	1	67	4
Specific conductance, field (μmhos/cm @ 25°C)	410	800	4,900
Water temperature (°C)	6.5	8.0	8.0

APPENDIX D

VEGETATION, SOIL WATER & SOIL DETACHABILITY

Table 21.--Soil moisture data and related data for the vegetation and soil sampling sites

SYMBOLS: H, HORIZON; DM, DEPTH IN DECIMETERS; VW, VOLUME WEIGHT IN GRAMS PER CUBIC CENTIMETER; SM, SOIL-MOISTURE CONTENT IN GRAMS PER GRAM; PF, LOG OF MOISTURE STRESS IN GRAMS PER SQUARE CENTIMETER; MRC, MOISTURE-RETENTION CAPABILITY AT PF 2.34 IN GRAMS PER GRAM; VMC, VOID-MOISTURE CAPACITY IN GRAMS PER GRAM; SMC, SATURATION-MOISTURE CAPACITY IN GRAMS PER GRAM; VS, VOLUMETRIC SHRINK IN CUBIC CENTIMETERS PER CUBIC CENTIMETER; EC, ELECTRICAL CONDUCTIVITY OF SATURATED SOIL IN MILLIMHOS PER CENTIMETER; PH, LOG OF HYDROGEN CONTENT IN MOLS PER LITER; ROOTS, WEIGHT OF ROOTS CONTAINED PER CUBIC DECIMETER OF SOIL; DET, DETACHABILITY OF SOIL BY FLOWING WATER IN KILOGRAMS PER HOUR FROM A SQUARE METER OF SURFACE; CPR, COARSE PARTICLE RATIO - WEIGHT OF PARTICLES OF DIAMETER GREATER THAN .25 MILLIMETERS DIVIDED BY TOTAL WEIGHT OF SOIL PARTICLES; MW, MOISTURE CONTENT WHEN WET IN GRAMS PER GRAM; MD, MOISTURE CONTENT WHEN DRY IN GRAMS PER GRAM; MDM, MOISTURE STORAGE DEPLETED IN DECIMETERS.

D 1

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
	1	1.12	.032	5.22	.124	0.51	0.38	.20	0.17	5.22	16.7	0.6	.022
1	2	1.28	.038	4.74	.099	0.40	0.27	.18	0.17	5.25	3.2	0.7	.024
	3	1.44	.037	4.71	.093	0.32	0.24	.17	0.14	5.95	1.7	0.7	.032
	4	1.51	.040	4.94	.120	0.28	0.24	.20	0.19	6.25	1.9	0.7	.031
	5	1.64	.035	4.62	.085	0.23	0.17	.14	0.12	6.75	1.1	0.7	.033
	6	1.79	.062	4.50	.139	0.18	0.36	.22	0.63	7.90	2.4	18.6	.038
2	7	1.88	.048	4.62	.115	0.15	0.27	.17	0.48	7.85	3.2	17.0	.043
	8	1.86	.097	4.42	.208	0.16	0.79	.52	2.00	8.05	1.6	0.6	.008
	9	1.67	.105	4.45	.230	0.22	0.79	.56	1.67	7.92	0.8	0.5	.002
	10	1.71	.115	4.27	.229	0.21	0.64	.48	2.55	8.22	0.4	6.5	.001
	11	1.66	.121	4.33	.247	0.23	0.92	.55	2.78	8.05	0.7	1.3	.001
	12	1.81	.119	4.32	.242	0.18	0.85	.60	2.08	7.95	0.3	0.4	.001
3	13	1.79	.121	4.33	.248	0.18	0.80	.52	3.68	7.70	0.4	1.7	.001
	14	1.80	.134	4.13	.247	0.18	0.92	.66	1.82	8.12	0.2	0.5	.001
	15	1.75	.127	4.28	.254	0.20	0.86	.61	1.79	8.20	0.3	0.4	.001
	16	1.75	.138	4.22	.266	0.20	0.74	.54	3.57	7.78	0.2	3.7	.001

D 2

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
	1	1.01	.060	4.43	.130	0.61	0.44	.25	0.21	5.12	15.7	0.6	.014
	2	1.18	.058	4.31	.116	0.47	0.31	.25	0.31	5.28	5.2	0.7	.016
	3	1.34	.062	4.24	.121	0.37	0.32	.27	0.31	5.82	4.7	1.8	.015
	4	1.39	.088	4.31	.179	0.34	0.43	.34	0.42	6.08	3.1	1.8	.007
1	5	1.47	.102	4.32	.208	0.30	0.51	.40	0.48	6.48	2.3	2.8	.002
	6	1.39	.079	4.23	.154	0.34	0.45	.37	0.53	7.25	5.8	4.5	.013
	7	1.41	.053	4.15	.099	0.33	0.29	.23	0.27	7.50	2.3	9.3	.028
	8	1.38	.073	4.02	.129	0.35	0.38	.33	0.45	7.78	2.2	5.9	.017
	9	1.46	.054	3.80	.087	0.31	0.30	.20	0.46	7.70	1.7	15.9	.034
	10	1.41	.055	3.36	.075	0.33	0.27	.16	0.86	7.62	1.7	35.5	.015
2	11	1.16	.094	2.30	.094	0.48	0.30	.19	1.25	7.95	1.2	23.7	.038
	12	1.20	.062	2.32	.062	0.45	0.25	.12	0.69	7.88	0.2	129.9	.066
	13	1.13	.105	1.89	.095	0.51	0.26	.19	1.04	8.02	0.7	28.6	.033
	14	1.15	.144	1.76	.126	0.49	0.32	.18	1.04	8.05	0.6	32.5	.020
	15	0.98	.147	2.18	.142	0.64	0.34	.31	1.52	7.48	0.8	5.6	.026
	16	1.15	.115	2.27	.113	0.49	0.31	.23	1.35	7.62	0.5	22.2	.035
	17	1.31	.112	1.81	.099	0.39	0.27	.18	0.96	7.55	1.2	23.6	.037
	18	1.50	.113	1.58	.095	0.29	0.27	.18	0.83	7.70	0.6	38.7	.036
	19	1.48	.078	1.47	.064	0.30	0.22	.12	0.48	7.75	0.3	53.7	.061
	20	1.52	.125	1.97	.115	0.28	0.25	.16	0.69	7.80	0.4	34.4	.044
	21	1.38	.133	1.26	.104	0.35	0.25	.17	0.66	7.85	0.3	53.2	.045
	22	1.64	.077	1.66	.066	0.23	0.25	.15	0.29	7.72	0.2	134.6	.067
	23	1.49	.112	1.21	.087	0.29	0.27	.14	0.49	7.75	0.9	87.1	.074
3	24	1.76	.146	1.36	.119	0.19	0.22	.11	0.56	7.72	0.7	41.5	.062
	25	1.41	.186	2.07	.175	0.33	0.23	.16	0.69	7.70	0.7	42.4	.053
	26	1.63	.234	0.79	.168	0.24	0.32	.19	0.71	7.82	0.1	38.1	.015
	27	1.63	.218	1.60	.184	0.24	0.25	.16	0.56	7.78	0.2	74.0	.057

H	DM	VW	SM	PF	MRC	VMC	SMC	VS	EC	PH	ROOTS	DET	CPR
						D 3							
	1	0.99	.084	4.67	.211	0.63	0.46	.21	0.39	6.18	25.8	0.5	.030
1	2	1.11	.093	4.42	.201	0.53	0.46	.26	0.30	6.18	16.7	0.6	.025
	3	1.35	.089	4.37	.187	0.37	0.47	.31	0.35	6.60	13.0	2.2	.012
	4	1.38	.101	4.17	.190	0.35	0.51	.34	0.42	7.35	6.9	8.4	.004
	5	1.37	.096	3.96	.166	0.36	0.51	.33	0.32	7.55	1.9	12.1	.002
	6	1.34	.108	3.97	.216	0.37	0.46	.29	0.35	7.80	1.5	15.1	.002
	7	1.35	.118	3.97	.203	0.36	0.47	.26	0.37	7.95	1.2	12.2	.002
	8	1.39	.145	3.64	.218	0.34	0.49	.32	0.33	8.08	1.9	13.2	.000
	9	1.48	.122	3.75	.192	0.30	0.44	.34	0.40	7.88	1.3	17.0	.003
	10	1.52	.101	3.69	.155	0.28	0.45	.34	0.45	7.75	0.2	17.4	.000
2	11	1.53	.156	3.63	.234	0.28	0.51	.35	0.54	8.25	1.8	19.1	.003
	12	1.49	.208	3.56	.304	0.30	0.61	.42	1.09	7.85	1.4	15.9	.001
3	13	1.46	.228	3.60	.338	0.31	0.69	.43	1.92	7.75	0.5	22.1	.000
	14	1.49	.239	3.62	.357	0.30	0.71	.43	2.08	7.48	0.4	17.0	.000
	15	1.48	.207	3.58	.304	0.30	0.71	.47	1.32	7.28	0.1	16.6	.000
	16	1.48	.208	3.56	.306	0.30	0.69	.52	1.56	7.40	0.3	17.7	.000
						D 4							
	1	1.09	.052	5.21	.196	0.54	0.40	.17	0.31	6.45	24.7	0.6	.049
	2	1.26	.058	5.03	.188	0.41	0.38	.19	0.29	6.38	11.1	0.6	.043
	3	1.44	.049	5.16	.176	0.32	0.31	.22	0.35	6.80	9.4	1.7	.046
1	4	1.59	.053	5.02	.169	0.25	0.32	.16	0.31	7.28	6.8	19.4	.049
	5	1.70	.050	4.71	.126	0.21	0.30	.14	0.22	7.38	4.5	36.7	.049
	6	1.87	.049	4.50	.111	0.16	0.24	.15	0.20	7.50	3.8	41.5	.060
	7	1.88	.069	4.01	.121	0.15	0.26	.21	0.23	7.38	2.6	8.3	.055
2	8	1.87	.083	3.58	.122	0.16	0.25	.18	0.23	7.65	1.1	14.3	.053
	9	1.75	.119	3.40	.164	0.19	0.36	.30	0.40	7.78	1.4	13.3	.022
	10	1.66	.143	3.43	.200	0.23	0.40	.33	0.63	8.12	2.9	9.6	.013
	11	1.58	.176	3.34	.237	0.25	0.45	.39	1.19	7.80	1.5	8.8	.007
3	12	1.65	.183	3.01	.222	0.23	0.43	.37	1.67	7.95	1.4	7.2	.010
	13	1.72	.162	2.44	.167	0.20	0.38	.33	1.64	7.75	1.0	8.2	.012
	14	1.62	.177	2.31	.176	0.24	0.40	.33	1.77	7.95	0.8	6.7	.004
	15	1.39	.180	2.31	.180	0.34	0.42	.29	1.77	7.98	1.1	6.8	.001
	16	1.39	.215	2.22	.209	0.34	0.44	.34	1.85	8.00	0.1	6.9	.001
						D 5							
	1	1.16	.106	4.85	.300	0.49	0.61	.31	1.85	6.70	56.2	0.5	.008
	2	1.46	.091	4.62	.219	0.31	0.45	.38	1.32	7.25	5.8	2.6	.015
1	3	1.60	.094	4.62	.228	0.25	0.46	.38	2.00	7.28	5.4	9.2	.019
	4	1.89	.110	4.64	.267	0.15	0.49	.45	2.50	7.28	3.2	3.1	.018
	5	1.82	.080	4.58	.188	0.17	0.37	.32	2.05	7.18	4.1	13.0	.031
	6	1.90	.060	4.52	.136	0.15	0.29	.22	1.25	7.39	2.2	41.6	.029
	7	1.77	.058	4.37	.120	0.19	0.28	.18	1.19	7.36	1.8	41.2	.041
	8	1.82	.088	4.34	.181	0.17	0.37	.29	1.25	7.39	1.3	15.4	.027
	9	1.70	.085	4.12	.156	0.21	0.35	.26	1.22	7.28	1.5	29.8	.029
	10	1.88	.105	3.76	.167	0.15	0.37	.32	1.43	7.42	0.5	27.5	.033
	11	1.79	.109	3.65	.164	0.18	0.33	.25	1.10	7.55	0.4	45.4	.042
2	12	1.84	.125	2.35	.126	0.17	0.29	.22	1.10	7.59	0.3	40.9	.032
	13	1.68	.145	2.17	.139	0.22	0.31	.27	1.32	7.39	0.3	23.0	.018
	14	1.75	.157	3.01	.190	0.19	0.44	.42	1.45	7.65	0.3	3.2	.021
	15	1.81	.171	3.12	.215	0.17	0.56	.36	1.52	7.61	0.3	2.7	.017
3	16	1.81	.172	2.28	.170	0.17	0.46	.40	1.39	7.59	0.4	4.3	.013

APPENDIX E

SOIL

(1) No. 1 1150'S.590'W. of $E\frac{1}{4}$ Cor. 0-24" friable Si.L., depths variable in area. 24-48" dark gray firm Si.Cl. 48-84" firm dark gray Cl. 84-120" till like firm loam with pebbles, dark gray.
P.M. - alluvial.
Lab. Nos. - R266-269

Depth	%S	%Si	%C	SAR
24-48	15.0	49.0	36.0	2.3
48-84	23.0	41.4	35.6	-

(2) No. 2 370'S.300'W. of $E\frac{1}{4}$ Cor. 0-12" friable, very dark grayish-brown S.L. 12-24" friable brown L. 24-42" calcareous FSL. 42-120" loose FSL.
P.M. - alluvium.
Lab. Nos. - R270-274.

(3) No. 3 900'W.600'S. of $E\frac{1}{4}$ Cor. 0-12" friable, heavy, sandy loam. 12-26" friable, heavy, dark brown Si.L. 26-42" calcareous L. firm. 42-102" firm glacial till.
P.M. - alluvial/till.
Lab. Nos. - R275-279.
Firm till 26"+.

(4) No. 4 1020'N.800'W. of SE Cor. 0-12" dark grayish-brown friable Si.L. 12-30" calcareous Si.L. 30-48" soft Lt. Fe. mottled Si.L. 48-72" gray Si.L. 72-90" Lt. Fe. mottled Si.L.
P.M. - residual.
Lab. Nos. - R280-285

Depth	SAR
90-120"	12

(5) No. 5 1420'W.480'N. of SE Cor. 0-10" very dark grayish-brown Si.L. 10-18" friable brown Si.L. 18-30" calcareous Si.L. 30-60" Lt. Fe. mottled Si.L. 60-102" Lt. Fe. mottled Si.L. 102-120" Si.L. residual, some salt crystals.
P.M. - alluvial/residual
Lab. Nos. - R286-290

Depth	SAR
30-60"	1.8

(6) No. 6 1320'N.1050'E. of $S\frac{1}{4}$ Cor. 0-12" friable, very dark grayish-brown L. 12-26" hard, prismatic loam. 26-84" friable soft Si.L. 84-120" residual siltstone.
P.M. - residual.
Lab. Nos. - R291-295

(7) No. 7 450'E.2200'N. of $S\frac{1}{4}$ Cor. 0-10" very dark grayish-brown friable Si.L. Thin A_2 horizon @ 10". 10-20" hard, prismatic, heavy L. 20-42" friable calcic Si.L. 42-56" Lt. Fe. mottled Si.L., salt crystals. 56-120" residual siltstone.
P.M. - residual.
Lab. Nos. - R296-301.

Depth	SAR
20-42"	12
42-56"	12

(8) No. 8 600'W.400'S. of $N\frac{1}{4}$ Cor. 0-10" friable, very dark grayish-brown Si.L. 10-20" hard, prismatic L. 20-42" calcareous Si.L. 42-60" Lt. Fe. mottled Si.L. 60"+ well weathered silt. 84"+ sodic.
P.M. - residual.
Lab Nos. - R302-306.

Depth	%S	%Si	%C	SAR
20-42"	-	-	-	12
42-60"	-	-	-	19
60-84"	4.0	73.6	22.4	-

(9) No. 9 850'S.580'W. of $N\frac{1}{4}$ Cor. 0-12" firm dark gray C. 12-30" firm calcic Cl. 30-42" firm Cl. 42-60" raw weathered shale.
P.M. - residual.
Lab. Nos. - R307-310.
Represents pan spot areas. 20% composition. Hole #10 for nonpan spot areas.

Depth	%S	%Si	%C	SAR
10-24"	-	-	-	13
24-48"	25.9	45.0	29.1	-

(10) No. 10 1160'N.400'W. of $S\frac{1}{4}$ Cor. 0-10" friable, very dark gray brown Si.L. 10-20" hard, prismatic Si.L. 20-48" calcareous platy Si.L. 48-66" shale. 66-78" silty shale.
P.M. - residual.
Lab. Nos. - R311-315.

Depth	SAR
48-66"	19
66-78"	14

(11) No. 11 360'W.240'N. of $S\frac{1}{4}$ Cor. 0-18"(A+B) friable, very dark grayish-brown to dark brown Si.L. 18-36" calcic Si.L. friable. 36-54" friable platy Si.L. 54-78" loose VFSL. 78-96" platy Si.L.
P.M. - alluvium.
Lab Nos. - R316-320
Friable profile.

(12) No. 12 1050'N.650'E. of SW Cor. Poor vegetation cover. 0-6" hard blocky clay, many roots. 6-120" weathered shale & siltstone, few roots to 60". Stiff 84-120".
P.M. - residual
Lab. Nos. - R321-326

Depth	%S	%Si	%C	SAR
6-24"	-	-	-	16
24-48"	-	-	-	20
48-60"	3.2	77.6	19.2	-
60-84"	-	-	-	20
84-120"	-	-	-	19

(13) No. 13 960'E.700'N. of SW Cor. 0-10" firm dark gray L. 10-18" calcic Si.C. 18-48" raw weathered Si.C., many roots, organic ions, firm. 48-120" friable Si.L. somewhat raw.
P.M. - residual.
Lab. Nos. - R327-332.

Depth	%S	%Si	%C	SAR
0-10"	30.5	43.5	26.0	-
18-48"	-	-	-	11
48-72"	29.6	50.1	20.3	-
96-120"	31.6	49.0	19.4	-

(14) No. 14 560'E.250'S. of $S\frac{1}{4}$ Cor. 0-18" friable, very dark grayish-brown FSL. 18-36" calcareous, friable VFSL. 36-120" friable VFSL & FSL.
P.M. - residual.
Lab. Nos. - R333-337.
0-18" excellent topsoil.
18-120"+ good subsoil.

(15) No. 15 1500'E.200'S. of $W\frac{1}{4}$ Cor. 0-10" firm, very dark gray Si.Cl. Thin A_2 horizon @ 10". 10-20" prismatic hard C. 20-42" firm Cl. 42-66" stiff C. 66-120" friable Si.Cl.
P.M. - residual.
Lab. Nos. - R338-343.

Depth	%S	%Si	%C
0-10"	9.1	59.5	31.4
42-66"	3.2	55.6	41.2

(16) No. 16 1080'E.900'S. of $W\frac{1}{4}$ Cor. 0-10" friable, very dark grayish-brown Cl. 10-20" blocky hard Si.Cl. 20-42" firm Cl. 42-60" firm Cl. 60-84" raw salt crystals, very firm. 84-96" raw, very fine Cl.
P.M. - residual.
Lab. Nos. - R344-344.

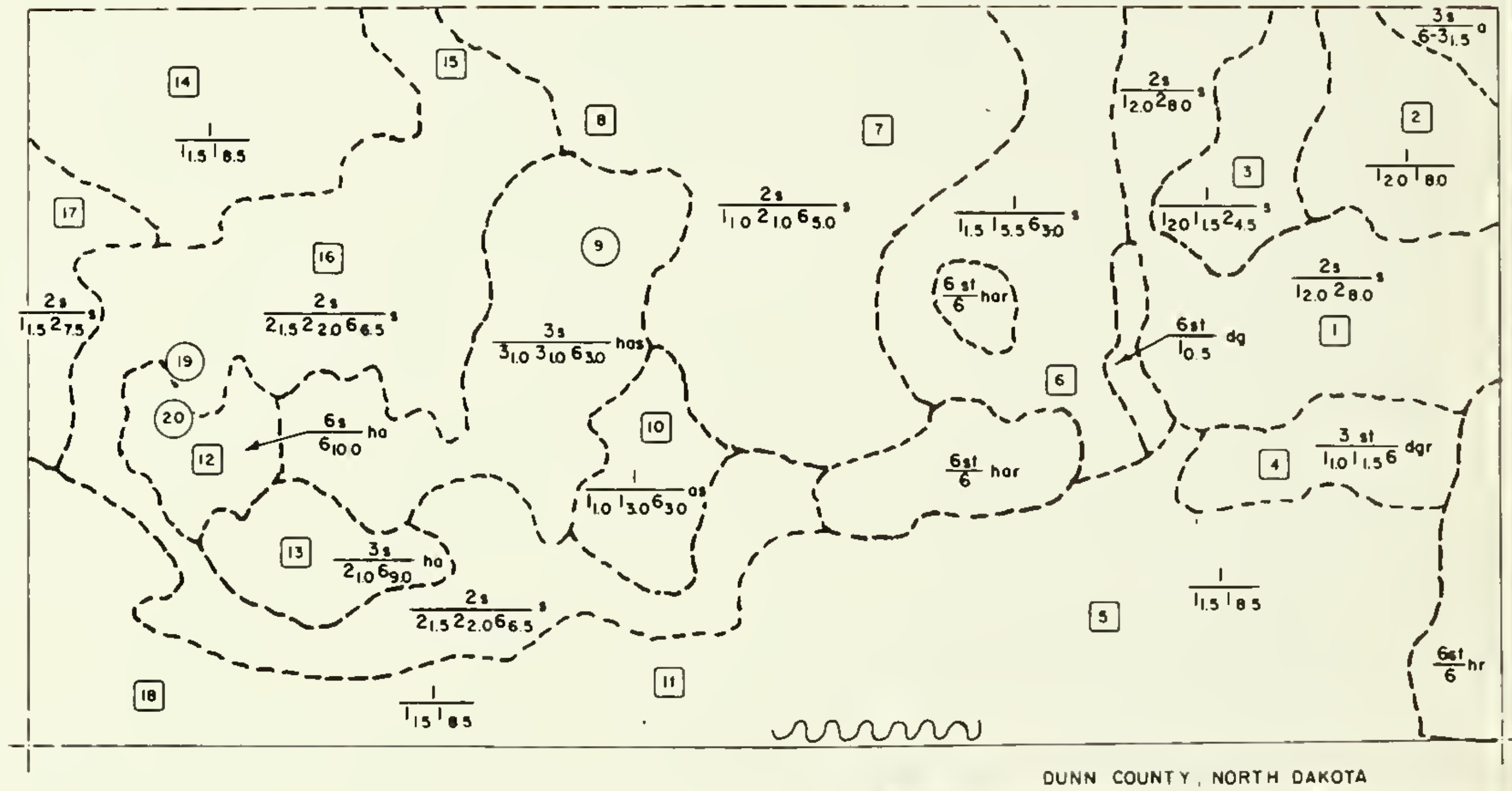
Depth	%S	%Si	%C
0-10"	11.8	64.7	23.5
10-20"	14.2	46.7	39.1
60-84"	9.6	45.2	45.2

(17) No. 17 730'S.150'E. of $W\frac{1}{4}$ Cor. 0-18" excellent topsoil. 18-54" good subsoil. 54-120" fair subsoil.
P.M. - residual.
Lab. Nos. - R350-355.
Scattered pan spots in area.

(18) No. 18 420'E.200'N. of SW Cor. 0-18" A+B good topsoil. 18-120" good subsoil.
P.M. - residual.
Lab. Nos. - R356-361.

(19) No. 19 1400'N.600'E. of SW Cor. Topsoil sample to provide mix for hole #20. Greenhouse sample.
P.M. - residual.

(20) No. 20 1000'N.650'E. of SW Cor. Greenhouse sample. Mix ½ with hole #9.
P.M. - residual.
Raw soil from shale.



LAND CLASSIFICATION SYMBOLS

LAND CLASS — 3 st — Plant media deficiency; Topographic deficiency
0 9 — Informative symbols
SURFACE LAYER: Quality, Depth — 2 5 3 / G 3 2 — GEOLOGIC MATERIAL: Quality, Depth
SECOND LAYER 1/: Quality, Depth
Divides soil material and nonsoil material

INFORMANTIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)

- s Salinity
- a Sodicity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- z Stoniness

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Massive lenticular sandstone and/or Glacial erotice
- c Cover

SOIL PROFILE NOTES

PROFILE REPRESENTS 5' DEPTH
[7] (3) SOIL PROFILE NUMBER

2.0 --- 2.5 EC.mmhos/cm. Sat. Ext.
8.4 — 8.0 8.4 pH: 8 Soil — Water Suspension; 8.0 pH Soil — $CaCl_2$ Suspension
------ .55 Hydraulic Conductivity in/hr. (Disturbed Samples)
.80/24 ------ 24 Settling Volume

SOIL PROFILE SYMBOLS

Symbol	Meaning
Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SIL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SICL	Silt Clay Loam
SC	Sandy Clay
C	Clay
SIC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

NOTE

1/ MAY INCLUDE SOME GEOLOGIC MATERIAL
2/ (3) 5 FOOT PROFILE
[7] 10 FOOT PROFILE OR TO HARD BEDROCK

MAP SYMBOLS

- SHELTER BELT
- SOIL PROFILE (Check)
- HOMESTEAD

400 0 400 800 SCALE OF FEET

DUNN COUNTY, NORTH DAKOTA
SEC. 3, T. 144 N. - R. 94 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

DETAIL LAND CLASSIFICATION

SOILS M.W. RONINGEN SUBMITTED ______
DRAWN L.E. ALLSOP RECOMMENDED ______
CHECKED ______ APPROVED ______
BILLINGS, MONTANA OCTOBER 1975 1305-600-100

No. 1 1270'S.370'E. of W¼ Cor. 0-48" good topsoil source. 48"+ best below 36"
P.M. - alluvium/residual.
Lab. Nos. - R177-181.

Depth	%S	%Si	%C	SAR
48-72"	1.1	68.1	30.8	-
72-96"	-	-	-	7.1

No. 2 540'E.220'S. of W¼ Cor. Glacial till 54"+.
P.M. - alluvium/glacial till.
Lab. Nos. - R182-187.

Depth	%S	%Si	%C
18-30"	41.7	31.4	27.9

No. 3 1600'E.50'S. of W¼ Cor.
P.M. - alluvium.
Lab. Nos. - 188-193.

Depth	%S	%Si	%C
8-20"	13.4	61.2	25.4
42-66"	51.7	25.7	22.6

No. 4 1060'E.970'N. of S¼ Cor. Vesicular, massive structure 30"+. 54-90" hard, firm.
P.M. - alluvium.
Lab. Nos. - R194-199.

No. 5 1800'N.100'E. of S¼ Cor. Very friable 0-22". Loose and single-grained 22-66".
P.M. - alluvium.
Lab. Nos. - R200-203.

Depth	%S	%Si	%C
10-22"	76.0	14.4	9.6

No. 6 1600'W.600'S. of E¼ Cor. Glacial till over alluvium @ 60". Other profiles in area are stony in spots.
P.M. - glacial till/alluvium.
Lab. Nos. - R204-209.

Depth	%S	%Si	%C	SAR
24-36	27.0	42.2	30.8	-
36-60	-	-	-	3.4

No. 7 1300'N.950'E. of S¼ Cor. Platy 0-3". Prismatic 3-22". Massive 22-66".
P.M. - old alluvium.
Lab. Nos. - R210-214.

Depth	%S	%Si	%C	SAR
0-10	28.0	40.7	31.3	-
22-42	11.1	49.6	39.3	9.4
42-54	-	-	-	12.0
54-66	24.5	33.6	41.9	-

No. 8 850'E.380'N. of S¼ Cor. Profile well suited for reconstruction.
P.M. - residual.
Lab. Nos. - R215-220.

No. 9 1050'N.530'E. of SW Cor.
P.M. - alluvium.
Lab. Nos. - R221-224.

No. 10 1150'W.1000'S. of NE Cor. 0-15" very dark grayish-brown friable, very fine sandy coal. 15-60" calcareous very friable VFSL. 60-84" Fe mottled friable Si.L. 84-120" very friable calcareous VFSL.
P.M. - alluvium.
Lab. Nos. - R225-230.
Very friable profile.

No. 11 650'S.600'W. of NE Cor. 0-12" very dark grayish-brown friable VFSL. 12-26" hard prismatic L. 26-36" friable calcareous Si.L. 36-102" very friable VFSL. Fe concentrations @ 102".
P.M. - alluvium.
Lab. Nos. - R231-235.

Depth	%S	%Si	%C
12-26"	49.3	33.2	17.5

No. 12 700'E.200'S. of N¼ Cor. 0-12" friable very dark grayish-brown Si.L. 12-24" slightly hard Si.L. 24-60" calcareous Si.L. 60-120" very friable VFSL.
P.M. - alluvium.
Lab. Nos. - R236-241.
Faint Fe mottling 84-120".

No. 13 600'S.40'E. of N¼ Cor. 0-18" friable, heavy, fine sandy loam. 18-36" firm calcareous heavy loam. 36-84" friable Si.L. 84-120" loose VFSL. Faint Fe mottling.
P.M. - alluvium.
Lab. Nos. - R242-246.
18-36" high inline.

No. 14 1470'S.100'E. of N¼ Cor. 0-18" dark brown friable S.L. 18-36" friable brown S.L. 36-60" Co.S.L. 60-84" loose brown S.L. 84-110" firm till, high in coal and pebbles.
P.M. - alluvial till.
Lab. Nos. - R247-251.
15-20% gravel 0-84".

No. 15 1900'W.500'N. of E¼ Cor. 0-7" dark gray, very friable, Lt. VFSL. 7-120" gray noncalcareous, loose LVFS.
P.M. - alluvium.
Lab. Nos. - R252-255.

No. 16 800'W.700'N. of E¼ Cor. 0-12" dark brown S.L. friable, 15-20% gravel. 12-24" friable S.L. 24-36" friable FSL. 36-120" loose LFS.
P.M. - alluvial.
Lab. Nos. - R256-260.

Depth	%S	%Si	%C
0-12"	77.2	12.9	9.9

No. 17 1400'W.40'N. of E¼ Cor. Friable heavy sandy loam with increasing gravels with depth. 10-25% gravel. Firm, oxidized glacial till 54-120"+. Thin sand lons @ 84".
P.M. - alluvium/till.
Lab. Nos. - R261-265.

Depth	%S	%Si	%C	%G
24-54"	84.0	7.5	8.5	38.0

No. 18 700'S.400'E. of NW Cor. 0-18" very dark grayish-brown S.L. 18-30" brown L.S. 18-48" loose lt. brown S.L. 48-72" calcareous friable S.L. 72-84" friable S.L. 84-120" somewhat raw heavy S.L.
P.M. - residual.
Lab. Nos. - R362-367.

No. 19 1000'N.450'E. of W¼ Cor. 0-18" very dark gray friable. 18-36" dark brown, friable, heavy S.L. 36-60" calcareous firm glacial till. 60-84" firm L. Thin F.S. lons 84-86". 86-120" firm, oxidized till.
P.M. - glacial till.
Lab. Nos. - 368-372.

No. 20 1250'S.1250'E. of NW. Cor. Boring located at crest of hill. Sandstone ranges from surface in areas to 29" in depth.
P.M. - residual.

No. 21 1300'N.1270'E. of W¼ Cor. Leeward side slope. 0-15" very friable lt. FSL. 15-60" very friable FSL. 60-84"+ lt. loose FSL. Represents narrow area on side slope.

No. 22 1100'W.350'S. of N¼ Cor. 0-12" friable very dark gray brown, heavy S.L. 12-30" calcareous, friable lt. loam. 30-60" friable L. 60-120" friable L., lt. Fe mottling.
P.M. - glacial till.
Lab. Nos. - R373-377.
Friable glacial till profile. Many glacial boulders scattered on crest of hill.

No. 23 1450'S.800'W. of N¼ Cor. 0-18" very dark grayish-brown friable VFSL. 18-30" very friable, brown FSL. 30-48" moderately calcareous friable L. 48-84" friable S.L. 84"+ firm Si.Cl. from silty shale.
P.M. - alluvium/residual.
Lab. Nos. - R378-382.

Depth	%S	%Si	%C
84-108"	17.8	56.2	26.0

No. 24 1850'E.750'N. of W¼ Cor. 0-18" friable dark brown S.L. 18-42" loose brown L.S. 42-84" loose L.S. 84-96" firm glacial till L. 96-120" loose L.S. with L. lons.
P.M. - alluvium.
Lab. Nos. - R383-387.
Scattered stones in area.

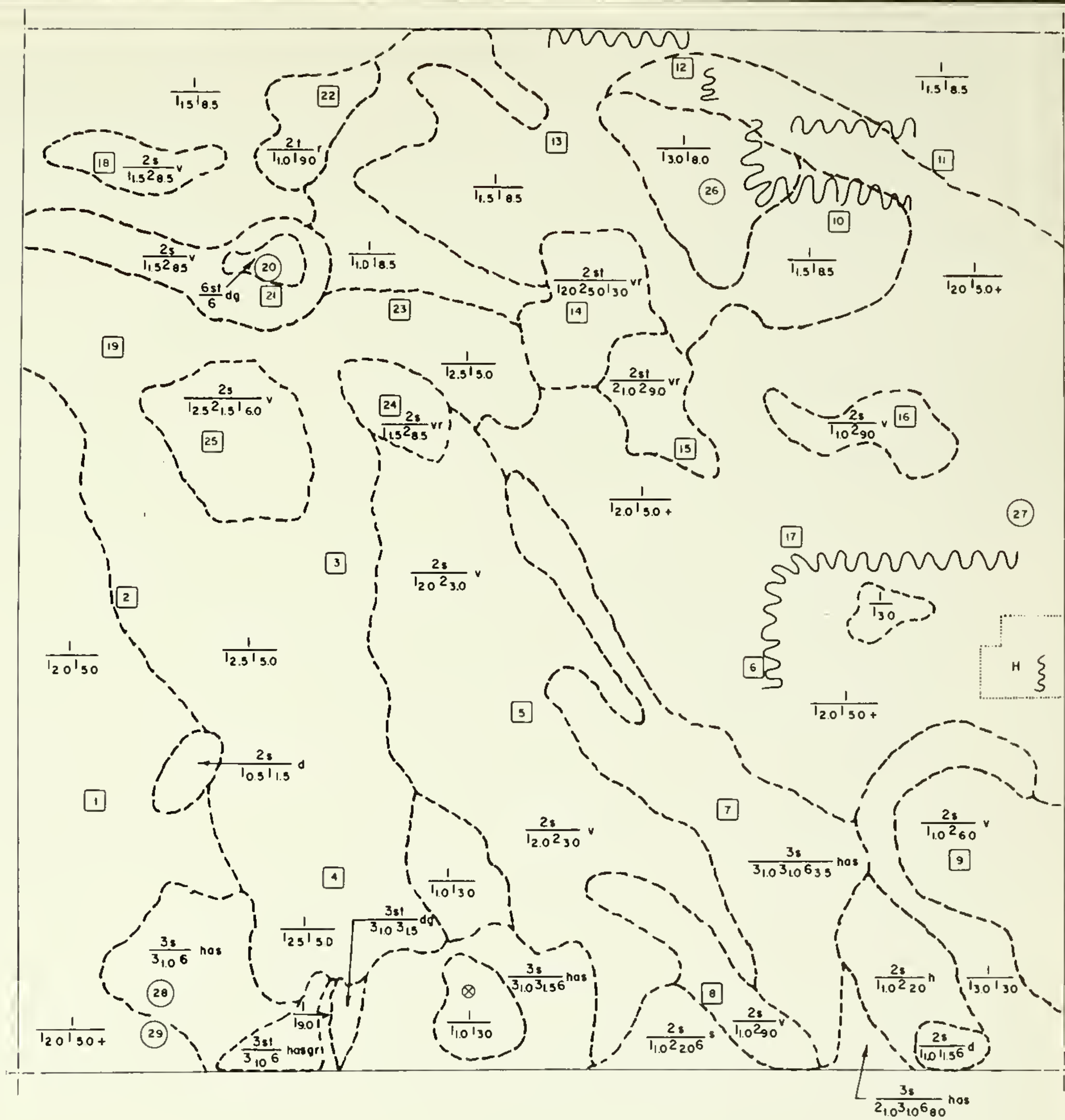
No. 25 950'E.550'N. of W¼ Cor. 0-10" very dark grayish-brown friable FSL. 10-30" dark brown friable S.L. 30-48" loose brown L.S. 48-120" firm till L., oxidized.
P.M. - alluvial/glacial till.
Lab. Nos. - R388-392.

No. 26 See Master site #3.

No. 27 See Master site #2.

No. 28 700'E.400'N. of SW Cor. Pan spot area sampled for greenhouse mix.
P.M. - residual.
Lab. No. - R685.

No. 29 700'E.200'N. of SW Cor. Class one soil area used for greenhouse mix with broing #28.
P.M. - residual.



LAND CLASSIFICATION SYMBOLS

LAND CLASS — 3 st — Plant media deficiency; Topographic deficiency
SURFACE LAYER — Quality, Depth — 2.5 3
SECOND LAYER 1/ — Quality, Depth
G 3 2 — GEOLOGIC MATERIAL — Quality, Depth
o g — Informative symbols
Divides soil material and nonsoil material

INFORMANTIVE SYMBOLS

OVERBURDEN DEFICIENCIES
(for plant media)

- Salinity
- Sodicity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- x Stoniness

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Massive lenticular sandstone and/or Glacial erratics
- c Cover

SOIL PROFILE NOTES

PROFILE REPRESENTS 5' DEPTH
7 / 3 SOIL PROFILE NUMBER

- 2.8 --- 2.5 EC, mmhos/cm, Sat. Ext.
- 8.4-8.0 8.4 pH 1:5 Soil-Water Suspension; 8.0 pH Soil-Ca Cl2 Suspension
- .85 Hydraulic Conductivity in/hr. (Disturbed Sample)
- 24 Swelling Volume

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silt Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

NOTE

1/ MAY INCLUDE SOME GEOLOGIC MATERIAL
2/ (3) 5 FOOT PROFILE
[7] 10 FOOT PROFILE OR TO HARD BEDROCK

MAP SYMBOLS

- SHELTER BELT
- ⊗ SOIL PROFILE (Check)
- [H] HOMESTEAD

400 0 400 800
SCALE OF FEET

DUNN COUNTY, NORTH DAKOTA
SEC. 10, T 144 N.- R 94 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

DETAIL LAND CLASSIFICATION

SOILS M.W. RONINGEN	SUBMITTED
DRAWN L.E. ALLSOP	RECOMMENDED
CHECKED	APPROVED
BILLINGS, MONTANA OCTOBER 1975	1305-600-101

No. 1 950'E.50'N. of S¼ Cor. 0-10" very dark grayish-brown loam. 10-24" brown friable loam, excellent for topsoil. 24-48" firm L. 48-72" loose S.L. 72-120" firm till L.
P.M. - glacial till.
Lab. Nos. - R421-425
Coal @ 120".

No. 7 2300'W.400'S. of E¼ Cor. 0-8" good topsoil. 8-24" fair to poor topsoil, good fill. 24-120" unsuitable material.
P.M. - residual.
Lab. Nos. - R648-652.
Pan spots in area.

No. 2 470'N.970'E. of S¼ Cor. 0-36" good for topsoil. 36-120" excellent subsoil material.
P.M. - alluvium.
Lab. Nos. - R426-430.
Concave position.

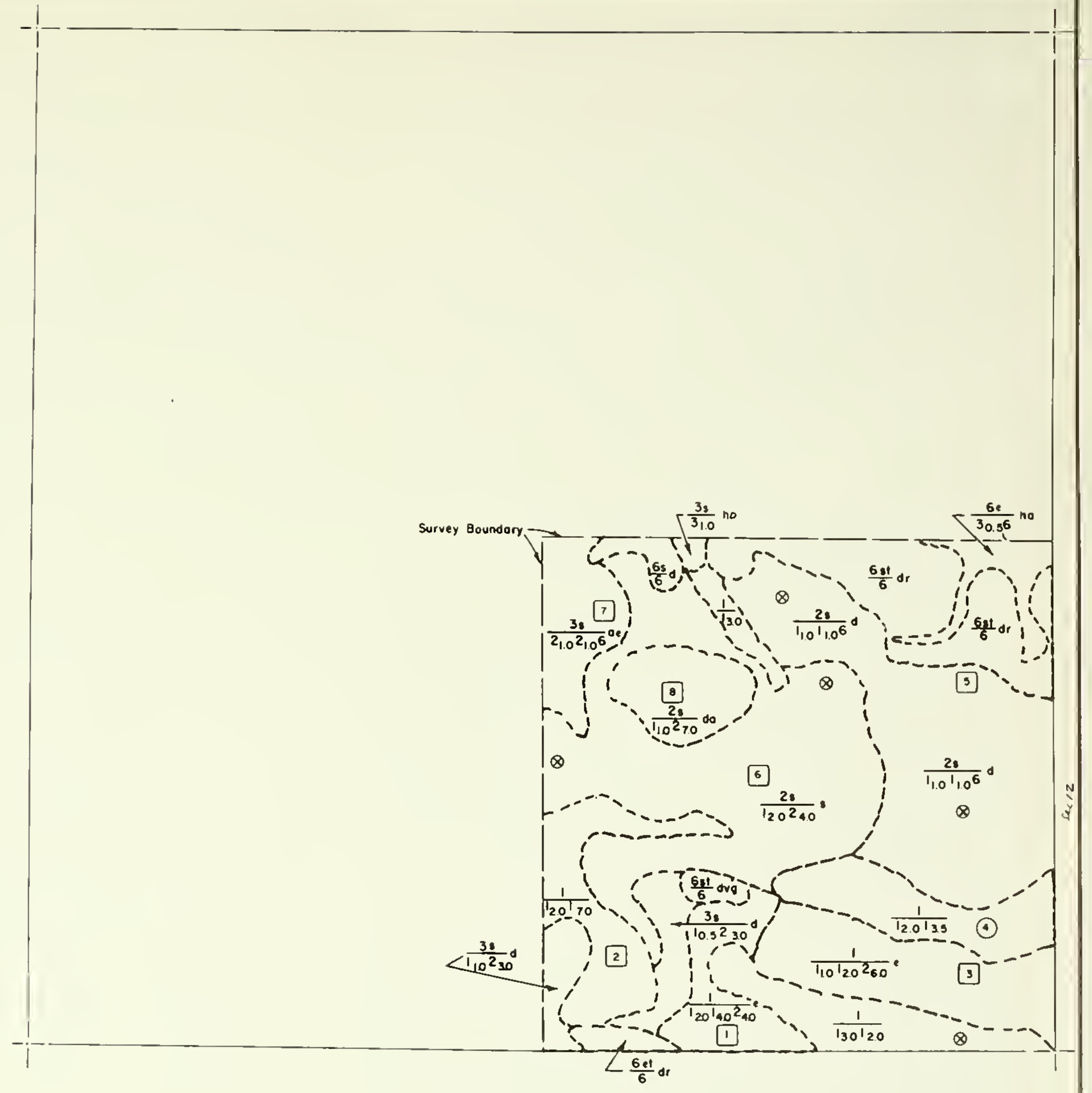
No. 8 1800'N.650'E. of S¼ Cor. 0-8" good topsoil. 8-24" weathered silty shale, oxidized, 24-96" friable when moist, hard, very hard dry silty beds.
P.M. - residual.
Lab. Nos. - R653-657.

No. 3 450'W.400'N. of SE Cor. 0-10" excellent topsoil. 10-20" reddish-brown friable Cl. 20-102"+ residual beds, calcareous silty shale.
P.M. - residual.
Lab. Nos. - R632-636.
20-36" greenhouse sample.

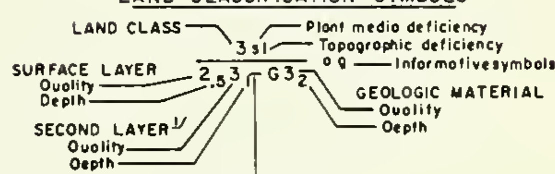
No. 4 650'N.350'W. of SE Cor. 0-18" excellent topsoil. 18-42" fair to good topsoil. 42-60" good fill material.
P.M. - alluvium.
Lab. Nos. - R637-640.

No. 5 750'S.450'W. of E¼ Cor. 0-10" good topsoil. 10-30" reddish-brown Si.L. Good fill. 30"+ scoria.
P.M. - scoria.
Lab. Nos. - R641-643.

No. 6 1400'N.1100'E. of S¼ Cor. 0-8" excellent topsoil. 8-20" fair topsoil. 20-66" suitable fill.
P.M. - residual.
Lab. Nos. - R644-647.



LAND CLASSIFICATION SYMBOLS



INFORMANTIVE SYMBOLS

OVERBURDEN DEFICIENCIES
(for plant media)

Salinity
Sodicity
h Clay (very fine texture)
v Coarse (very sandy texture)
p Restricted permeability
q Available moisture capacity
d Depth of suitable overburden
z Stoniness

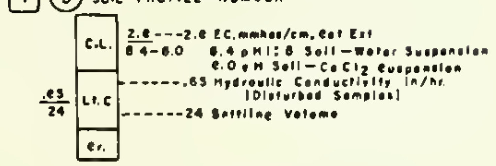
TOPOGRAPHIC DEFICIENCIES

g Slope (including gradient and complexity)
r Massive lenticular sandstone and/or Glacial erratics
c Cover

SOIL PROFILE NOTES

PROFILE REPRESENTS 5' DEPTH

[7] (3) SOIL PROFILE NUMBER



SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SIL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SICL	Silt Clay Loam
SC	Sandy Clay
C	Clay
SIC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

NOTE

1/ MAY INCLUDE SOME GEOLOGIC MATERIAL

2/ (3) 5 FOOT PROFILE

[7] 10 FOOT PROFILE OR TO HARD BEDROCK

MAP SYMBOLS

SHELTER BELT

SOIL PROFILE (Check)

HOMESTEAD

SCALE OF FEET: 400 0 400 800

DUNN COUNTY, NORTH DAKOTA
SEC. 11, T 144 N - R 94 W

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

DETAIL LAND CLASSIFICATION

SOILS M. W. RONINGEN ---- SUBMITTED ----
DRAWN L. E. ALLSOP ---- RECOMMENDED ----
CHECKED ---- APPROVED ----

BILLINGS, MONTANA | OCTOBER 1975 | 1305—600—102

No. 1 320'N.20'W. of S¼ Cor. 0-7" firm Cl. suitable for topsoil, 7-30" calcic sodic Cl., 30-66" raw bedded silty shale, 7-66" not suitable for reclamation. P.M. - residual. Lab. Nos. - R461-464. Few scattered stones in area.

No. 2 800'N.750'W. of S¼ Cor. 0-15" clay suitable for topsoil. 15"+ unsuitable for profile reconstruction. P.M. - alluvial/residual. Lab. Nos. - R465-470.

No. 3 650'W.400'N. of S¼ Cor. 0-10" good topsoil, 10-30" suitable for fill material, 30-120" residual material, sodic unsuitable for profile reconstruction. P.M. - residual. Lab. Nos. - R471-476.

No. 4 1250'W.150'N. of S¼ Cor. 0-15" suitable for topsoil, 15-48" suitable for fill, may be used for topsoil. 48-66" suitable below 24", 66-114"+ placed below 36" in reconstructed profile. P.M. - alluvial/residual. Lab. Nos. - R477-480. Pan spots to west. Suitable topsoil to 18".

No. 5 900'E.600'N. of SW Cor. 0-6" good topsoil, 6-12" B2t horizon suitable fill, 12-48" saline, sodic, 48'108" raw residual material best placed below 36". P.M. - alluvial/residual. Lab. Nos. - R483-489.

No. 6 1400'N.100'E. of SW Cor. 0-10" A+B2t suitable topsoil, 10-30" fair fill, 0'96" residual beds suitable for fill. P.M. - Residual. Lab. Nos. - R490-494.

No. 7 550'E.150'N. of W¼ Cor. 0-11" A+B2t horizons, 60"+ hard gray shale. P.M. - alluvial/residual. Lab. Nos. - R495-498.

No. 8 1050'E.800'N. of W¼ Cor. Soil unsuited for reclamation, raw soil from shale 24"+. P.M. - alluvial/residual. Lab. Nos. - R499-501.

No. 9 1320'S.100'W. of N¼ Cor. 0-13" good topsoil material, 13-33" B2t hard prismatic. Shallower solums surrounding area, 33-120" glacial till. 120-132" coal. P.M. - glacial till. Lab. Nos. - R502-506. Pan areas @ 12" depth side slopes and area to east.

No. 10 600'S.220'E. of NW Cor. 0-8" excellent topsoil, 8-20" but with weak columnar structure, hard, 20-48" salt crystals friable, 48-120" friable residual beds. Suitable for fill. P.M. - residual. Lab. Nos. - R507-511.

No. 11 1200'W.620'S. of N¼ Cor. 0-12" excellent topsoil, 12-20" but hard, 20-48" saline, 48"+ weathered beds. P.M. - residual. Lab. Nos. - R512-517. Solum shallower in area (6" to clay pan) 104"¼ dk. brn. L.

No. 12 1200'E.500'S. of W¼ Cor. 0-8" good topsoil, 8-18" B2t hard soil, 18-36" suitable fill material, 36-104" bedded Si.C. oxidized to 84" unoxidized 84"+. P.M. - residual. Lab. Nos. R518-523. Pan spots in area.

No. 13 1900'E.600'N. of W¼ Cor. 0-24" friable L. suitable topsoil, 24" A2 horizon, 24-36" B2t hard, 36-90" firm clay, suitable for fill. P.M. - alluvium. Lab. Nos. - R524-528. Columnar clay pan in area 6-12" depth, average 12".

No. 14 2000'S.30'W. of N¼ Cor. 0-8" good quality topsoil, 8-20" B2t horizon hard, 20-42" hard olive gray calcareous Cl., 42-54" hard C., 54-108" sticky plastic very dark gray Cl. P.M. - alluvium. Lab. Nos. - R529-534. Water table 54". Mixed entire profile suited for topsoil.

No. 15 1400'S.25'W. of N¼ Cor. 0-30" very friable Sl. suitable for topsoil 30-120" glacial till loam suitable for fill. P.M. - glacial till. Lab. Nos. - R535-539.

No. 16 350'S.50'W. of N¼ Cor. 0-10" good topsoil, 10-30" fair to poor topsoil good fill, 30-48" good fill, 48-120" fair to poor fill. P.M. - alluvium. Lab. Nos. - R540-544.

No. 17 880'W.550'S. of N¼ Cor. 0-60" excellent friable very dark gray topsoil, 60-78" good fill material, 78-120" stiff clay. P.M. - alluvium. Lab. Nos. - R545-549.

No. 18 2200'N.250'E. of S¼ Cor. 0-8" friable L. good topsoil, 8-72"+ baked rock. P.M. - residual. Lab. Nos. - N.S.

No. 19 1500'N.900'W. of S¼ Cor. 0-20" excellent topsoil, 20-30" fair fill material, 30-96"+ sodic. P.M. - residual. Lab. Nos. - R550-555. Residual beds at 30" calcareous, silty shale.

No. 20 1150'N.650'E. of S¼ Cor. Thin sandstone lens at 30", 84-120" few gypsum crystals, 0-6" fair topsoil, 6-30" poor fill, 30-120" raw soil from shale. P.M. - residual. Lab. Nos. - R556-561. Clay pan throughout area.

No. 21 1950'W.150'S. of E¼ Cor. 0-18" good topsoil material, 18-36" good fill material, 36"+ scoria. Clay pan in area @ 6-18" depth. P.M. - scoria. Lab. Nos. - R562-565.

No. 22 1400'W.500'S. of E¼ Cor. 0-20" good to excellent topsoil (A+B Horizon) 20-36" fair topsoil B2 Horizon, 36-54" good fill, 54-96" fair to poor fill, 96"+ residual. P.M. - alluvium. Lab. Nos. - R566-571.

No. 23 670'E.270'N. of S¼ Cor. 0-8" excellent topsoil, 8-18" weakly developed clay pan may be mixed with topsoil, 18-120" suitable for fill. P.M. - glacial till. Lab. Nos. - R572-577. Firm till 18"+.

No. 24 1050'W.850'N. of SE Cor. 0-18" excellent topsoil, 18-42" suitable for topsoil, (Brn.) 42-90" fair-quality fill. P.M. - alluvium/residual. Lab. Nos. - R578-582.

No. 25 1050'E.450'S. of N¼ Cor. 0-20" good to fair topsoil, 20-84" good fill, 84-120" fair glacial till fill. P.M. - alluvium over till. Lab. Nos. - R583-588. Some surface soil dispersion in area, very weak clay pan in moderately fine soils.

No. 26 1800'S.850'E. of N¼ Cor. 0-18" excellent topsoil, 18-120" firm glacial till oxidized. P.M. - glacial till. Lab. Nos. - R589-593.

No. 27 1050'W.700'N. of E¼ Cor. 0-18" A+B2t Horizon suitable for topsoil, 18-30" suitable for fill, 30-60" saline, 60-84" stiff raw, 84-120" suitable for fill. P.M. - alluvium. Lab. Nos. - R594-600.

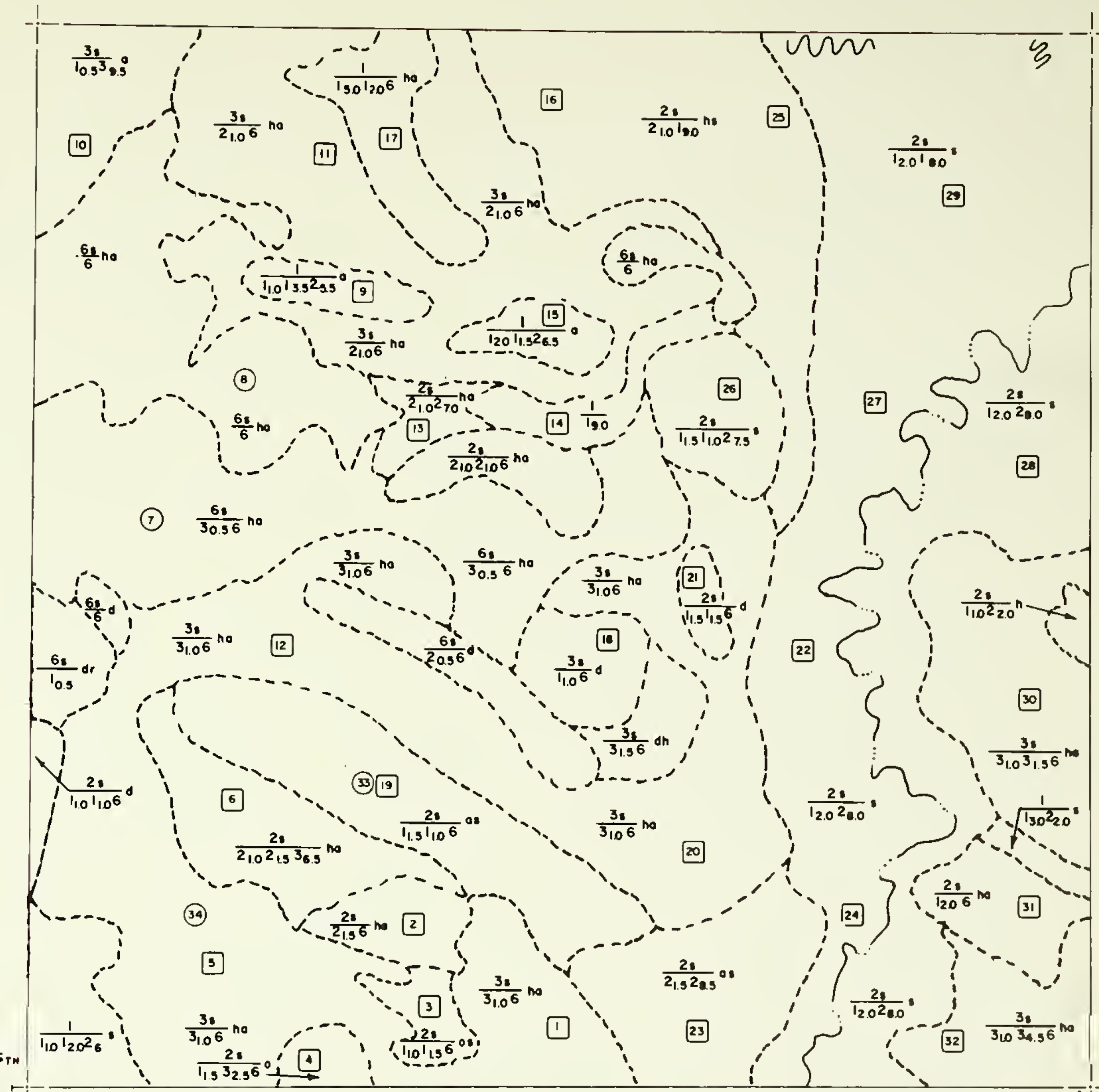
No. 28 400'N.200'W. of E¼ Cor. 0-18" excellent topsoil, 8-24" fair to poor topsoil B2t, 24-120" good fill material. P.M. - alluvium. Lab. Nos. - R601-606.

No. 29 800'S.650'W. of NE Cor. 0-24" good topsoil A+B, heavier with depth, 24-90" good fill material, 90-108" buried topsoil. 108-120" loose loamy sand and 10% gravel. P.M. - recent alluvium. Lab. Nos. - R607-612.

No. 30 750'S.300'W of E¼ Cor. 0-12" excellent topsoil. 12-24" heavy B2t Horizon, 24-34" C.Ca. Horizon, 34-120" firm raw residual material oxidized to 96". P.M. - residual. Lab. Nos. - R613-619. Clay pan 6" 50% of area to east.

No. 31 850'N.300'W. of SE Cor. 0-20" excellent topsoil, 20-24" heavy B2t Horizon, 24-120" raw heavy residual beds. Mildly oxidized. P.M. - residual. Lab. Nos. - R620-624.

No. 32 650'W.220'N. of SE Cor. 0-8" good quality topsoil, 8-13" firm B2t Horizon, 13-48" suitable fill material. 48-66" oxidized residual beds, 66-120" unoxidized residual material. P.M. - alluvium over-residual. Lab. Nos. - R625-631. @ 50% clay pan in area boring located in nonclay pan area.



LAND CLASSIFICATION SYMBOLS

Land class — Plant media deficiency — Topographic deficiency — Informative symbols

Surface layer: Quality, Depth — Second layer: Quality, Depth — Geologic material: Quality, Depth

Divides soil material and nonsoil material

INFORMANTIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)

Salinity
Sodicity
h Clay (very fine texture)
v Coarse (very sandy texture)
p Restricted permeability
q Available moisture capacity
d Depth of suitable overburden
s Stoniness

TOPOGRAPHIC DEFICIENCIES

g Slope (including gradient and complexity)
r Massive lenticular sandstone and/or Glacial erratics
c Cover

SOIL PROFILE NOTES

PROFILE REPRESENTS 5' DEPTH
7 3 SOIL PROFILE NUMBER
E.S---E.S EC mmhos/cm. Sat. Ext.
8.4-6.0 8.4 pH: 5 Soil-Water Suspension; 6.0 pH Soil-CaCl2 Suspension
.86 Hydraulic Conductivity in/hr. (Disturbed Samples)
24 Settling Volume

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
C	Clay
SiC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

NOTE
1/ MAY INCLUDE SOME GEOLOGIC MATERIAL
2/ (3) 5 FOOT PROFILE
[7] 10 FOOT PROFILE OR TO HARD BEDROCK

MAP SYMBOLS

SHELTER BELT
SOIL PROFILE (Check)
HOMESTEAD

400 0 400 800 SCALE OF FEET

DUNN COUNTY, NORTH DAKOTA
SEC. 12, T. 144 N.-R. 94 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

DETAIL LAND CLASSIFICATION

SOILS M.W. RONNIGEN — SUBMITTED
DRAWN L.E. ALLSOP — RECOMMENDED
CHECKED — APPROVED
BILLINGS, MONTANA — OCTOBER 1975 — 1305-600-103

(1) No. 1 570'W.350'N. of SE Cor. Contact lens of angular gravels @ 24". 10-42" raw material pebbles and gravel present 60"+ material placed below 3' in reconstructed profile. P.M. - glacial till/residual. Lab. Nos. R103-108.

(2) No. 2 950'W.370'N. of SE Cor. 0-24" excellent topsoil. 24-60" suitable for subsoil material. P.M. - residual with glacial overide. Lab. Nos. - R109-112.

(3) No. 3 1000'N.600'E. of S¼ Cor. Somewhat raw 96"+. P.M. - residual. Lab. Nos. R113-118.

(4) No. 4 1680'N.720'E. of S¼ Cor. Dense material 30"+. 0-12" suitable for topsoil, 12-30" heavy Cl. Better for submaterial. P.M. - glacial till. Lab. Nos. - R119-123.

(5) No. 5 410'N.60'W. of SE Cor. Friable good quality material to 102". 102"+ slowly permeable material. P.M. - alluvium. Lab. Nos. - 124-130.

(6) No. 6 350'N.250'E. of S¼ Cor. 0-18" excellent topsoil, 18-60" suitable for subsurface placement. P.M. - residual. Lab. Nos. - R131-134.

(7) No. 7 600'E.50'S. of NW Cor. SE¼. Profile well suited for reconstruction purposes. P.M. - alluvium. Lab. Nos. - R135-139.

(8) No. 8 1300'W.330'S. of E¼ Cor. Sandy loam lens 36-38". Profile not suited for reclamation. P.M. - alluvium. Lab. Nos. - R140-144.

(9) No. 9 800'W.500'S. of E¼ Cor. 0-7" excellent topsoil, 7"+ hard when dry. P.M. - alluvium. Lab. Nos. - R145-149.

(10) No. 10 480'E.150'S. of W¼ Cor. P.M. - alluvium. Lab. Nos. R150-155.

(11) No. 11 1290'E.220'S. of W¼ Cor. Clay pan areas on side slopes. P.M. - glacial till. Lab. Nos.-R156-162.

(12) No. 12 1250'N.900'W. of S¼ Cor. 0-38" good topsoil. 66"+ residual. P.M. - alluvium/residual. Lab. Nos. - R163-169.

Depth	%S.	%Si.	%C.
38-48"	10.4	75.3	14.3

(13) No. 13 330'E.260'N. of SW Cor. Residual 60"+ sandier soils in area. P.M. - alluvium/residual. Lab. Nos. - R170-173.

(14) No. 14 930'W.440'N. of S¼ Cor. 0-18" satisfactory topsoil material. 72"+ weathered siltstone. P.M. - alluvial/residual. Lab. Nos. - R174-176.

(15) No. 15 980'W.520'N. of E¼ Cor. 0-15" dark brown friable Sl., 15-30" Brown very friable Sl., 30-48" brown friable L., 48-90" Si.Cl. from weathered silty shale. P.M. - alluvial/residual. Lab. Nos. - R393-397.

(16) No. 16 680'N.750'E. of SW Cor. ¼. 0-18" very dark grayish brown friable, heavy L. 8-36" dark brown, heavy friable L. 36"+ well weathered Fe, mottled Si.Cl. & Si.C. from silty shale. P.M. - residual. Lab. Nos. - R398-402

(17) No. 17 500'N.300'E. of SW Cor.¼. 0-10" friable, very dark brown L. 10-20" dark brown S.L. 20-48" friable FSL. 48-84" reworked residual, Si.L. friable. 84-120" silty shale with fine sand & pebbles. P.M. - alluvial/residual. Lab. Nos. - R403-408.

(18) No. 18 800'E.350'S. of N¼ Cor. 0-24" very dark grayish-brown friable L. 24-36" dark brown L. 36-42" friable Cl. 42-84" loose L.S. 84-120" firm Cl. P.M. - alluvial. Lab. Nos. - R409-413

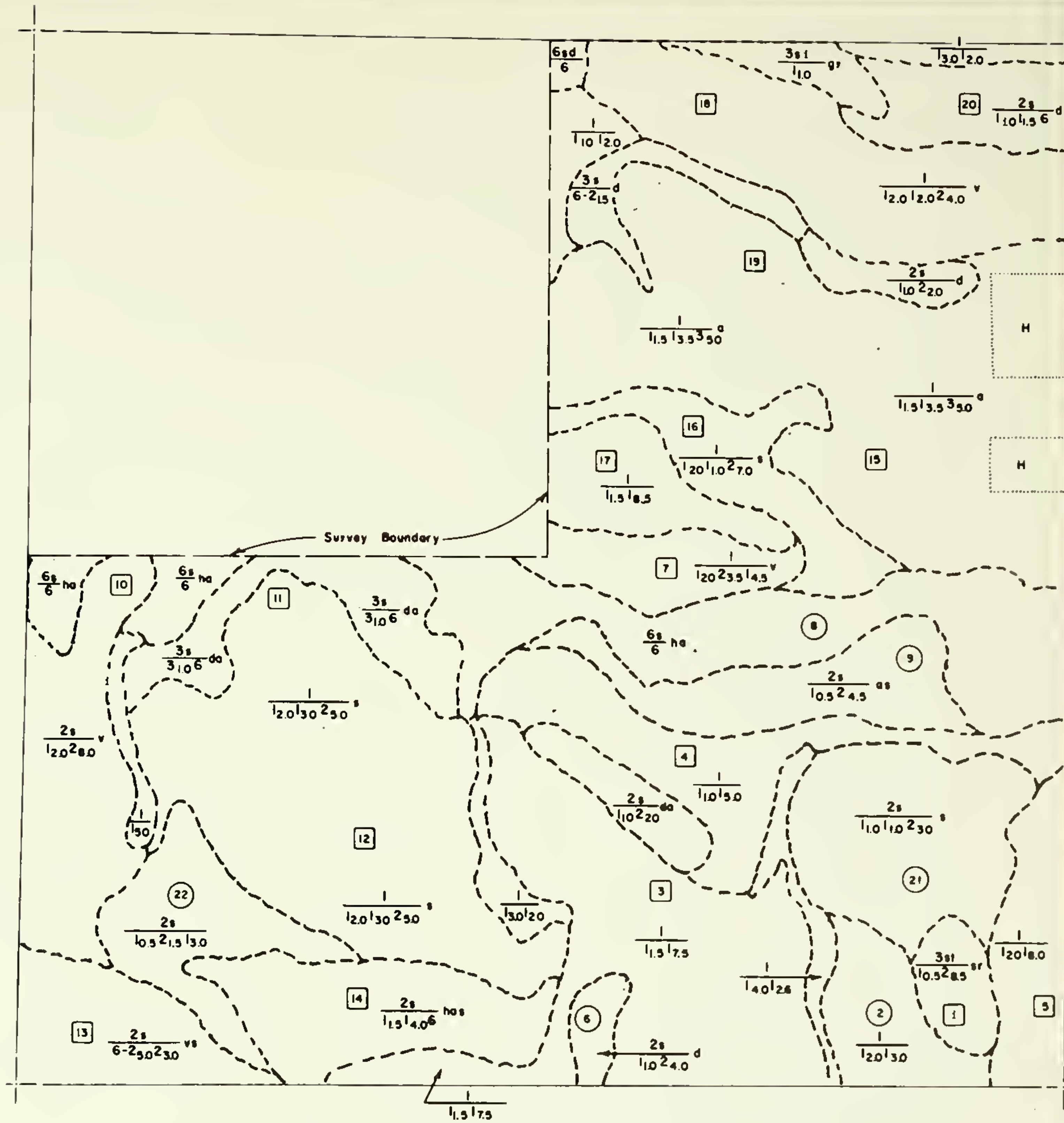
Depth	%S.	%Si.	%C.
36-54"	37.7	37.2	25.1

(19) No. 19 1150'S.1050'E. of N¼ Cor. 0-18" friable, dark grayish-brown L. 18-36" dark brown friable FSL. 36-120" firm Si.C., weathered silty shale. P.M. - alluvial/residual. Lab. Nos. - R414-418 84-120" sample slightly contaminated with surface soils.

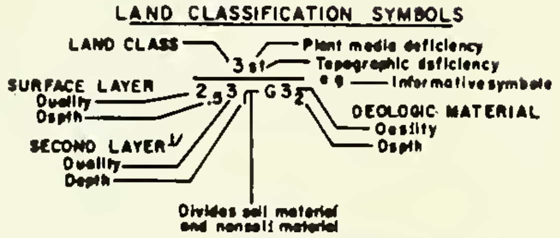
(20) No. 20 520'W.330'S. of NE Cor. 0-12" friable, very dark grayish-brown L. 12-30" firm till like L. 30"+ coal. P.M. - residual. Lab. Nos. - R419-420.

(21) No. 21 1050'N.800'W. of SE Cor. 0-10" excellent topsoil. 10-24" suitable fill. 24-42" suitable fill 42-60" weathered siltstone. P.M. - residual. Lab Nos. - R672-675.

(22) No. 22 950'N.800'E. of SW Cor. 0-10" friable Cl. 10-14" coal. 14-26" firm C. 26-60" raw soil from silty shale. P.M. - residual. Lab. Nos. - R676-678.



LAND CLASSIFICATION SYMBOLS



INFORMANTIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)

- Salinity
- Sodicity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- s Stoniness

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Massive lenticular sandstone and/or Glacial erratics
- c Cover

SOIL PROFILE NOTES

PROFILE REPRESENTS 5' DEPTH

[7] (3) SOIL PROFILE NUMBER

2.0 ---2.0 EC.mmhos/cm. Sat. Sol.
5.4-6.0 5.4 pH 1:5 Soil-Water Suspension; 6.0 pH Soil-CaCl₂ Suspension
-----.55 Hydraulic Conductivity in/hr. (Disturbed Samples)
-----54 Settling Volume

SOIL PROFILE SYMBOLS

Symbol	Meaning
Cb	Cobble
Gr	Gravel
S	Sand
L.S	Loamy Sand
SL	Sandy Loam
L	Loam
SIL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SICL	Silt Clay Loam
SC	Sandy Clay
C	Clay
SIC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

NOTE

1/ MAY INCLUDE SOME GEOLOGIC MATERIAL

2/ (3) 5 FOOT PROFILE

[7] 10 FOOT PROFILE OR TO HARD BEDROCK

MAP SYMBOLS

- SHELTER BELT
- SOIL PROFILE (Check)
- HOMESTEAD

400 0 400 800
SCALE OF FEET

DUNN COUNTY, NORTH DAKOTA
SEC. 14, T. 144 N.- R 94 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

DETAIL LAND CLASSIFICATION

SOILS M.W. RONINGEN SUBMITTED
DRAWN L.E. ALLSOP RECOMMENDED
CHECKED APPROVED
BILLINGS, MONTANA OCTOBER 1975 1305-600-104

No. 1 650'E.75'S. of NW Cor. Excellent topsoil 0-22". Good subsurface fill 22-84".

Depth	%S	%Si	%C
0-15"	55.9	30.1	14.0
15-22"	58.4	26.6	15.0
22-36"	56.1	30.7	13.2
36-60"	52.3	37.0	10.7
60-72"	57.4	32.2	10.4
72-84"	60.8	28.1	11.1

P.M. - residual.
Lab. Nos. - R24-29

No. 2 1230'E.75'S. of NW Cor. Area averages 8-12" of voclaimable lower quality topsoil. Substrata unsuitable.
P.M. - residual.
Lab Nos. - R30-34

Depth	SAR
0-8"	5.1

No. 3 975'E.620'S. of NW Cor. Entire soil profile suitable for topsoil.
P.M. - alluvium.
Lab. Nos. - R35-40.

No. 4 1270'S.990'E. of NW Cor. Excellent topsoil to 20", material 20-108"+ suitable for subsurface fill material. Roots on structure faces 20-42".
P.M. - residual.
Lab. Nos. - R41-48.

No. 5 2610'E.470'N. of $W\frac{1}{4}$ Cor. Good topsoil to 18". 18"+ good subsurface material. Gravel contact lens @ 18".
P.M. - alluvial.
Lab. Nos. - R49-55.

No. 6 2320'W.1330'N. of $E\frac{1}{4}$ Cor. 0-10" excellent topsoil. 10-84" somewhat raw soil from siltstone but suitable for subsurface.
P.M. - residual.
Lab. Nos. - R56-60.

No. 7 920'W.70'S. of NE Cor. Represents old alluvial flat clays have good structure & are permeable. 0-10" excellent topsoil material. 10-24" fair to poor. 24-120" unsuitable.
P.M. - alluvial.
Lab. Nos. - R61-68.

Depth	%S	%Si	%C	SAR
0-10"	15.8	60.6	23.6	1.7
10-18"	12.4	50.9	37.0	3.9
18-24"	12.2	52.5	35.3	-
24-36"	-	-	-	0.6

No. 8 650'N.330'W. of $E\frac{1}{4}$ Cor. Topsoil good 0-12". Good substratum to 42". 42"+ $CaSO_4$ crystals. Raw soil from siltstone 12"+.
P.M. - residual.
Lab. Nos. - R69-73.

Depth	SAR
24-42"	29

No. 9 630'E.210'S. of $N\frac{1}{4}$ Cor. 0-15" good topsoil material. 15-120" fair for fill.
P.M. - residual.
Lab. Nos. - R74-80.

Depth	SAR
96-120"	2.2

No. 10 1060'S.270'E. of NW Cor. 0-28" fair topsoil material. 28-42" good subsurface material 42-84" acceptable for surface, good subsurface material.
P.M. - residual.
Lab. Nos. - R81-86.

Depth	SAR
0-6"	3.1

No. 11 500'E.100'N. of $W\frac{1}{4}$ Cor. Raw soil from shale 12"+. $CaSO_4$ lens 40-54".
P.M. - residual.
Lab. Nos. - R87-91.

No. 12 950'E.130'N. of $W\frac{1}{4}$ Cor.
P.M. - residual.
Lab. Nos. - R92-97.

Depth	SAR
66-84"	1.9

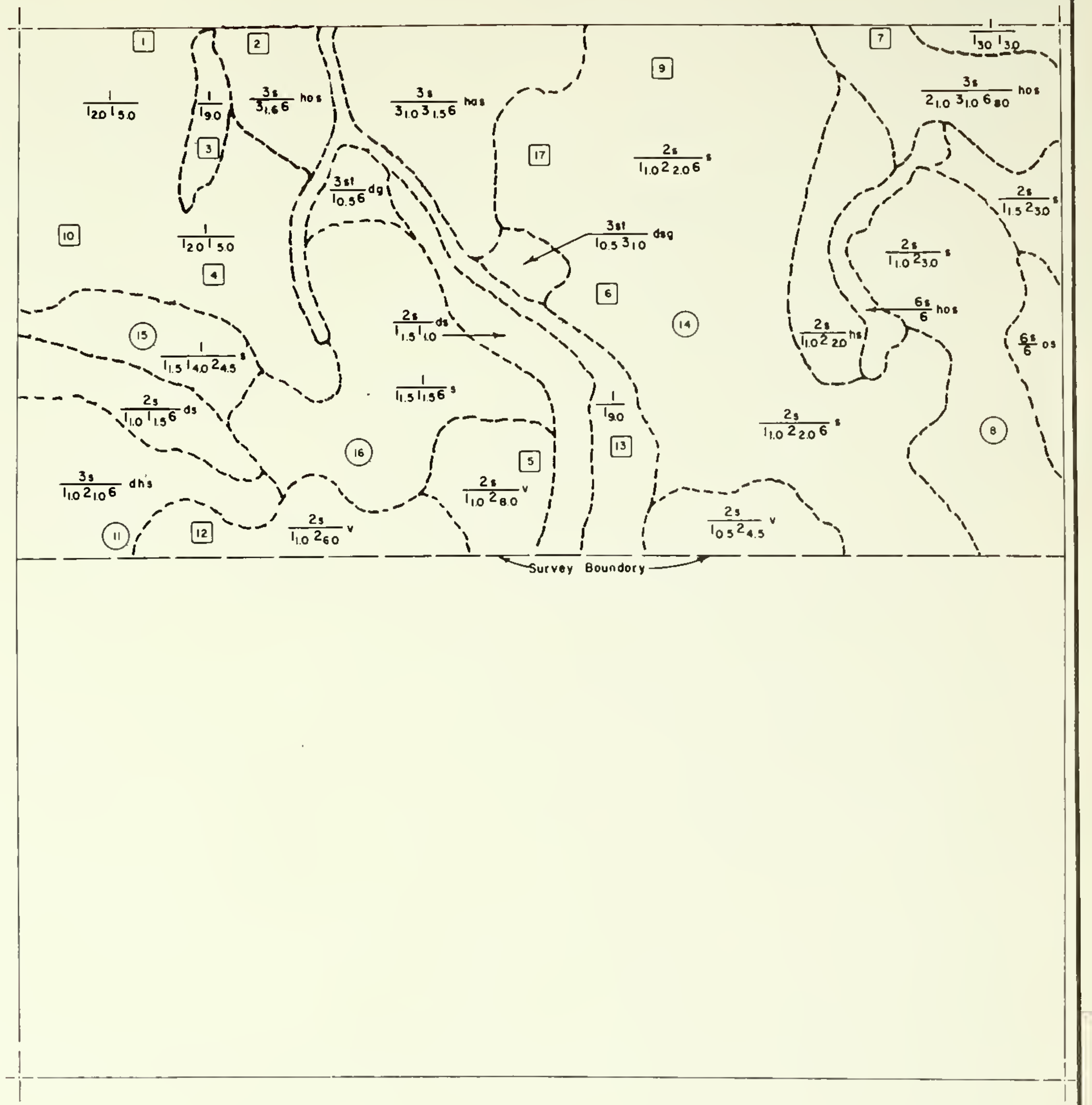
No. 13 2040'W.540'N. of $SE\frac{1}{4}$ Cor. Profile suitable for topsoil material.
P.M. - alluvium.
Lab. Nos. - R98-102

No. 14 1520'S.700'E. of $N\frac{1}{4}$ Cor. See Morton Master site.

No. 15 1100'N.650'E. of $W\frac{1}{4}$ Cor. See Son Master site.

No. 16 1720'E.500'N. of $W\frac{1}{4}$ Cor. 0-15" good topsoil. 15-30" firm Cl. subsoil. 42-66" bedded silty shale.
P.M. - residual.
Lab. Nos. - R679-681.

No. 17 650'S.50'W. of $N\frac{1}{4}$ Cor. 0-15" A+B horizon suitable for topsoil. 15-42" suitable for fill. 42-66" weathered siltstone.
P.M. - residual.
Lab. Nos. - R682-684.



LAND CLASSIFICATION SYMBOLS

LAND CLASS — 3 st — Plant media deficiency; Topographic deficiency; a g — Informative symbols
SURFACE LAYER: Quality, Depth — 2.5 3
SECOND LAYER 1/: Quality, Depth
Divides soil material and nonsoil material
G 3 2 — GEOLOGIC MATERIAL: Quality, Depth

INFORMANTIVE SYMBOLS

OVERBURDEN DEFICIENCIES (for plant media)

- Salinity
- Sodicity
- h Clay (very fine texture)
- v Coarse (very sandy texture)
- p Restricted permeability
- q Available moisture capacity
- d Depth of suitable overburden
- s Stoniness

TOPOGRAPHIC DEFICIENCIES

- g Slope (including gradient and complexity)
- r Massive lenticular sandstone and/or Glacial erratics
- c Cover

SOIL PROFILE NOTES

PROFILE REPRESENTS 5' DEPTH

7 (3) SOIL PROFILE NUMBER

C.L. — 2.8 - - - 2.8 EC mmhos/cm, Sat. Ext.; 8.4-8.0 — 8.4 pH 1:5 Soil-Water Suspension; 8.0 pH Soil-CaCl2 Suspension
Lt.C — .65 Hydraulic Conductivity in/hr. (Disturbed Samples); 24 Settling Volume
Gr.

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SIL	Silt Loam
SCL	Sandy Clay Loam
CL	Clay Loam
SICL	Silt Clay Loam
SC	Sandy Clay
C	Clay
SIC	Silty Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

NOTE

1/ MAY INCLUDE SOME GEOLOGIC MATERIAL

2/ (3) 5 FOOT PROFILE

[7] 10 FOOT PROFILE OR TO HARD BEDROCK

MAP SYMBOLS

- SHELTER BELT
- SOIL PROFILE (Check)
- HOMESTEAD

400 0 400 800
SCALE OF FEET

DUNN COUNTY, NORTH DAKOTA
SEC. 15, T. 144 N. - R 94 W.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
HORSE NOSE BUTTE STUDY AREA
DUNN CENTER LIGNITE FIELD

DETAIL LAND CLASSIFICATION

SOILS M.W. RONINGEN — SUBMITTED
DRAWN L.E. ALLSOP — RECOMMENDED
CHECKED — APPROVED
BILLINGS, MONTANA — JULY 1975 — 1305-600-105

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Master Site No. 1

Study Area: Horse Nose Butte, North Dakota
Location. Sec. 15 Twp. 144N Range 94W
1520'S, 700'E of NW Cor. of NE¼, 4 mi.S & 2 mi. E of Dunn Center, Dunn County
Climate: Semi-arid
Land Use: Pasture

Relief: Simple convex
Elevation: 2,300'
Slope: Aspect: 3 percent
Vegetation: Western wheatgrass, Bluegrass, Fringed sage
Erosion: Slight

Stoniness: None
Drainage: Well
Ground Water: None to 120 inches
Land Form: Nearly level to very gently sloping sedimentary uplands

Parent Material: Residuum from soft siltstone
Soil Series: Morton silt loam
Soil Classification: Fine-silty, mixed family of Typic Haploborolls
Profile Description By: M.R. Wright, M.Roningen Date: 10/21/75

LAB NO.	DEPTH (cm)	PROFILE DESCRIPTION
R431	0-13 Alp	Dark grayish brown (10YR 4/2) loam, very dark brown (10YR 2/2) moist; moderate granular structure; slightly hard, friable, slightly sticky and slightly plastic; many very fine to medium roots; common fine pores; abrupt smooth boundary.
R432	13-41 B21t	Dark yellowish brown (10YR 4/4) clay loam, dark brown (10YR 3/3) moist; moderate medium prismatic structure parting to strong medium blocky structure; very hard, firm, sticky and plastic; common fine roots; common very fine pores; many moderately thick clay films on face of peds; gradual wavy boundary.
R433	41-69 B22t	Light yellowish brown (2.5Y 6/4) clay loam, dark grayish brown (2.5Y 4/2) moist; moderate medium prismatic structure parting to moderate medium blocky structure; hard, firm, sticky and plastic; common fine roots; common very fine pores; common thin clay films; gradual irregular boundary.
R434	69-94 Cca	Light olive gray (5Y 6/2) loam, olive gray (5Y 5/2) moist; few fine distinct yellowish brown (10YR 5/6) mottles; weak fine platy structure; violent effervescence; common fine soft masses of lime; few fine roots; gradual irregular boundary.
R435	94-152 C1r	Light olive gray (5Y 6/2) soft siltstone, olive grey (5Y 4/2) moist; common large distinct light yellowish brown (2.5Y 6/4) mottles; weak fine platy structure; slightly effervescence; few fine roots; gradual boundary.
R436	152-229 C2r	Light olive gray (5Y 6/2) soft siltstone, olive (5Y 4/3) moist; few medium faint olive brown (2.5Y 4/4) mottles; weak medium platy structure; slightly effervescence; few salt crystals in lower part; few fine roots; gradual boundary.
R437	229-305 C3r	Multi-colored, mottled, soft siltstone; slightly effervescence.

LABORATORY DESCRIPTION

DETERMINATION		DATA						
LABORATORY NUMBER		R431	R432	R433	R434	R435	R436	R437
DEPTH	(cm)	0-13	13-41	41-69	69-94	94-152	152-229	229-305
PARTICLE SIZE ANALYSIS	(percent)							
Very Coarse Sand	(2.0-1.0 mm)							
Coarse Sand	(1.0-0.5 mm)							
Medium Sand	(0.5-0.25 mm)							
Fine Sand	(0.25-0.10 mm)							
Very Fine Sand	(0.10-0.05 mm)							
Total Sand	(2.0-0.05 mm)	24.5	21.0	12.1	21.1	26.2	21.8	22.7
Silt	(0.05-0.002 mm)	56.4	52.9	63.7	60.0	53.5	60.4	60.8
Clay	(<0.002 mm)	19.1	26.1	24.2	18.9	20.3	17.8	16.5
TEXTURAL CLASS (LAB.)		SiL	SiL	SiL	SiL	SiL	SiL	SiL
BULK DENSITY	(g/cm^3)	1.31	1.42	1.41	1.43	1.47	1.40	
HYDRAULIC CONDUCTIVITY	(cm / hr)							
6th hr		0.36	1.02	0.66	0.51	0.10	0.25	1.42
24th hr		0.66	1.83	0.71	0.51	0.10	0.10	1.32
SETTLING VOLUME	(ml)	22	22	23	21	45	28	25
MOISTURE RETENTION	(percent)							
1/10 bar		36.6	30.5	34.8	34.3	36.4	36.2	36.6
1/3 bar		23.2	23.1	25.9	32.7	34.7	24.9	31.7
15 bar		10.8	11.6	11.0	9.4	11.8	10.9	10.8
SOIL REACTION-pH								
Paste								
1:5 H_2O		6.9	6.8	7.8	9.0	9.6	9.1	8.3
1:2 0.01 M $CaCl_2$		6.4	6.3	6.8	7.7	8.1	8.2	7.8
ORGANIC CARBON	(percent)							
AVAILABLE PHOSPHORUS	(ppm)							
$CaCO_3$ EQUIVALENT	(percent)							
GYPSUM REQUIREMENT	(me/100g)	+1.1	-0.6	-0.1	-0.2	+1.8	-0.4	-6.3
SATURATION EXTRACT								
Saturation Percentage		45.5	41.4	45.3	46.0	53.6	52.2	45.5
EC_e @ 25°C	(mmhos/cm)	0.51	0.41	0.69	0.60	2.01	7.0	12.0
Ca^{++}	(me/l)	2.42	2.31	3.40	1.37	0.77	5.87	22.07
Mg^{++}	(me/l)	2.53	2.17	3.98	2.71	4.43	39.80	99.51
Na^{+}	(me/l)	0.24	0.41	0.67	2.58	15.09	42.17	61.74
K^{+}	(me/l)	1.00	0.21	0.18	0.17	0.28	0.70	1.03
CO_3^{-}	(me/l)	0.00	0.00	0.00	0.00	0.24	0.12	0.00
HCO_3^{-}	(me/l)	2.72	1.58	6.08	4.62	5.16	2.54	1.72
Cl^{-}	(me/l)	0.22	0.00	0.00	0.00	0.37	0.93	1.80
SO_4^{-}	(me/l)	0.92	1.00	0.48	0.70	15.00	83.73	182.40
NO_3^{-}	(me/l)	0.06	0.07	0.08	0.31	0.34	0.29	1.16
SAR		0.2	0.3	0.4	1.8	9.4	8.8	7.9
Na	(me/100g)	0.01	0.02	0.03	0.12	0.81	2.20	2.81
Ca+Mg	(me/100g)	.22	.19	.33	.18	.28	2.39	5.53
1:5 EXTRACT								
EC_5 @ 25°C	(mmhos/cm)	0.13	0.12	0.15	0.20	0.45	1.0	2.2
Ca+Mg	(me/100g)	0.4	0.4	1.0	1.0	0.3	1.7	8.4
EXCHANGEABLE SODIUM	(percent)	0.2	0.3	0.3	2.0	6.5	8.4	8.3
ACIDITY								
1N KCl exchange acidity								
Total	(me/100g)							
Al^{+++}	(me/100g)							
CATION EXCHANGE CAPACITY	(me/100g)	21.2	21.6	20.2	19.4	20.0	20.4	20.0
NaOAc@pH 8.2								
BORON	(mg/l)							

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Master Sits No. 2

Table 26

Study Area: Horee Noee Butts, North Dakota
Location. Sec. 10 Twp. 144N Range 94W
800'S, 840'E of NW Corner of NE¼, Dunn County
Climate: Semi-erid
Land Use: Cultiveted

Relief: Simple, elightly conceve
Elevation: 2,230'
Slope: Aspect: 1 percent
Vegetation: Small grein etubble
Erosian: Slight

Staniness: None
Drainage: Well
Ground Water: Deep
Land Form: Large depreseion in reeidual uplands

Parent Material: Local elluvium
Sail Series: Arnegerd loam
Sail Classification: Fine-loamy, mixed family of Pachic Haploborolls
Profile Description By: M.R. Wright, M.Roningen Date: 10/21/75

LAB NO.	DEPTH (cm)	PROFILE DESCRIPTION
R438	0-25 Ap	Dark grayish brown (10YR 4/2) loam, very dark brown (10YR 2/2) moist; moderate granuler structure; friable, many fine roots; few worm ceets; few medium poree; ebrupt smooth boundary.
R439	25-76 B21	Dark grayieh brown (2.5Y 4/2) loam, very dark grayish brown (2.5Y 3/2) moiet; moderete medium and fine prismatic etructure parting to moderete medium and fine subangulsr blocky etructure; elightly hard, friable; few fine roots; common very fine pores; gradual boundary.
R440	76-91 B22	Dark greyish brown (2.5Y 4/2) loam, very dark brown (10YR 2/2) moist; etructure same ee horizons ebove; slightly hard, friable; few fine roote; common very fine pores; clear wavy boundary.
R441	91-104 B3	Light yellowish brown (2.5Y 6/4) loam, olive brown (2.5Y 4/4) moist; moderate medium and fine prismatic structure parting to strong medium blocky etructure; slightly hard; few fine roots; oleer wavy boundary.
R442	104-129 C1ca	Light yellowish brown (2.5Y 6/4) loam, light olive brown (2.5Y 5/4) moist; weak ooarse prismatic structure parting to moderate medium and fine subangular structure; many fine soft maeses of lime; violent efferveeoence; few stones; clear wavy boundary.
R443	129-173 C2ca	Olive yellow (2.5Y 6/6) loam, light olive brown (2.5Y 5/6) moist; moderete fine eubangular blocky etructure; very few roots; violent effervescence; few fine eoft masees of lime; gredual boundary.
R444	173-335 IIC1	Light olive grey (5Y 6/2) loamy fine sand, olive grey (5Y 5/2) moist; noncalcareous; few fine roots in upper part.

LABORATORY DESCRIPTION

DETERMINATION		R438	R439	R440	R441	R442	R443	R444
LABORATORY NUMBER		R438	R439	R440	R441	R442	R443	R444
DEPTH	(cm)	0-25	25-76	76-91	91-104	104-129	129-173	173-335
PARTICLE SIZE ANALYSIS	(percent)							
Very Coarse Sand	(2.0-1.0 mm)							0.0
Coarse Sand	(1.0-0.5 mm)							0.2
Medium Sand	(0.5-0.25 mm)							0.7
Fine Sand	(0.25-0.10 mm)							38.1
Very Fine Sand	(0.10-0.05 mm)							33.1
Total Sand	(2.0-0.05 mm)	42.0	49.7	49.5	50.0	32.8	37.2	72.1
Silt	(0.05-0.002 mm)	43.5	33.6	34.5	34.6	46.6	45.4	22.4
Clay	(< 0.002 mm)	14.5	16.7	16.0	15.4	20.6	17.4	5.5
TEXTURAL CLASS (LAB.)		L	L	L	L	L	L	VFSL
BULK DENSITY	(g/cm³)	1.39	1.51	1.53	1.52	1.58	1.66	
HYDRAULIC CONDUCTIVITY	(cm / hr)							
6th hr		0.25	1.42	1.12	1.02	0.25	0.46	1.62
24th hr		0.25	1.22	1.02	0.96	0.25	0.41	1.52
SETTLING VOLUME	(ml)	19	18	18	18	20	20	16
MOISTURE RETENTION	(percent)							
1/10 bar		33.6	23.6	24.4	22.7	28.5	28.1	16.3
1/3 bar		24.9	16.9	16.7	20.1	23.3	20.7	11.4
15 bar		10.9	7.0	6.7	5.9	6.7	7.3	2.7
SOIL REACTION-pH								
Paste								
1:5 H_2O		6.5	7.1	7.2	8.2	8.7	8.7	9.1
1:2 0.01 M $CaCl_2$		5.7	6.2	6.8	7.1	7.7	7.8	7.9
ORGANIC CARBON	(percent)							
AVAILABLE PHOSPHORUS	(ppm)							
$CaCO_3$ EQUIVALENT	(percent)							
GYPSUM REQUIREMENT	(me/100g)	+0.5	0.0	0.0	-0.4	-0.9	-1.0	0.0
SATURATION EXTRACT								
Saturation Percentage		38.5	36.3	30.9	34.0	41.1	33.0	30.0
EC_e @ 25°C	(mmhos/cm)	1.2	0.30	0.31	0.69	0.72	0.86	0.59
Ca^{++}	(me/l)	3.46	1.70	1.76	3.79	3.79	3.02	1.43
Mg^{++}	(me/l)	1.81	1.00	1.09	2.71	3.45	4.70	2.99
Na^{+}	(me/l)	0.43	0.20	0.26	0.37	0.41	0.71	1.17
K^{+}	(me/l)	1.57	0.18	0.19	0.31	0.30	0.16	0.18
CO_3^{-}	(me/l)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3^{-}	(me/l)	1.84	1.68	1.72	4.40	3.72	4.02	2.46
Cl^{-}	(me/l)	0.00	0.02	0.00	0.00	0.00	0.00	0.25
SO_4^{-}	(me/l)	1.90	0.52	0.72	0.78	0.72	0.71	1.32
NO_3^{-}	(me/l)	1.48	0.11	0.14	1.18	2.98	3.50	1.82
SAR		0.3	0.2	0.2	0.2	0.2	0.4	0.8
Na	(me/100g)	0.02	0.01	0.01	0.01	0.02	0.02	0.04
Ca+Mg	(me/100g)	.20	.10	.08	.22	.30	.26	.13
1:5 EXTRACT								
EC_5 @ 25°C	(mmhos/cm)	0.72	0.14	0.13	0.17	0.19	0.19	0.13
Ca+Mg	(me/100g)	0.7	0.4	0.7	0.9	0.9	1.3	0.7
EXCHANGEABLE SODIUM	(percent)	0.2	0.2	0.2	0.2	0.3	0.8	1.0
ACIDITY								
IN KCl exchange acidity								
Total	(me/100g)							
Al^{+++}	(me/100g)							
CATION EXCHANGE CAPACITY	(me/100g)	20.6	15.0	14.6	11.0	11.6	10.2	4.0
NaOAc@pH 8.2								
BORON	(mg/l)							

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Master Site No. 3

Table 27

Study Area: Horse Nose Butte, North Dakota
Location. Sec. 10 Twp. 144N Range 94W
150'W, 75'N of SE Cor. of NE¼, Dunn County
Climate: Semi-arid
Land Use: Cultivated

Relief: Simple, concave and convex
Elevation: 2,260'
Slope: Aspect: 1 percent
Vegetation: Small grain stubble
Erosion: Slight

Stoniness: None
Drainage: Well
Ground Water: Deep
Land Form: Nearly level area in gently undulating uplands

Parent Material: Aeolian sands over glacial till
Soil Series: Flaxton light loam
Soil Classification: Fine-loamy, mixed family of Pachic Argiborolls
Profile Description By: M.R. Wright, M.Roningen Date 10/23/75

LAB NO.	DEPTH (cm)	PROFILE DESCRIPTION
R445	0-20 Alp	Dark grayish brown (10YR 4/2) light loam, very dark grayish brown (10YR 3/2) moist; granular structure; friable; nonsticky, nonplastic; common fine roots; abrupt smooth boundaries.
R446	20-43 B21	Grayish brown (2.5Y 5/2) light loam, very dark grayish brown (2.5Y 3/2) moist; weak coarse prismatic structure parting to medium subangular blocky structure; friable; nonsticky, nonplastic; common fine roots; fine tubular roots; clear wavy boundaries.
R447	43-58 IIB22t	Light olive gray (5Y 6/2) clay loam, dark grayish brown (2.5Y 4/2) moist; strong coarse and medium prismatic structure parting to strong coarse and medium subangular blocky structure; firm, sticky, plastic; few fine roots; clear irregular boundaries.
R448	58-96 IICca	Light brownish gray (2.5Y 6/2) clay loam, grayish brown (2.5Y 5/2) moist; strong coarse and medium prismatic structure parting to strong coarse and medium subangular blocky structure; firm, slightly sticky, slightly plastic; few fine roots; violent effervescence; medium masses of segmented lime; clear boundaries.
R449	96-112 IIC1	Light brownish gray (2.5Y 6/2) clay loam till, grayish brown (2.5Y 5/3) moist; strong coarse and medium prismatic structure parting to coarse and medium subangular blocky structure; firm; slightly sticky, slightly plastic; few fine roots; few small pebbles; strong effervescence; clear boundaries.
*	112-122 IIIC1	Yellowish brown (10YR 5/6) gravelly loam, brown or dark brown (7.5YR 4/4); single grain structure; nonsticky, nonplastic; few fine roots; many large sand grain particles and many small pebbles; strong effervescence; gradual boundaries.
R450	122-147 IVC1	Light brownish gray (2.5Y 6/2) silt loam; light olive brown (2.5Y 5/4) weak medium platy structure; nonsticky, nonplastic; strong effervescence; gradual wavy boundaries.
R451 & R452	147-305 VC1	Loamy very fine sand.
		* No sample taken

LABORATORY DESCRIPTION

DETERMINATION		R445	R446	R447	R448	R449	R450	R451	R452
LABORATORY NUMBER		R445	R446	R447	R448	R449	R450	R451	R452
DEPTH	(cm)	0-20	20-43	43-58	58-96	96-112	112-122	122-147	147-305
PARTICLE SIZE ANALYSIS	(percent)								
Very Coarse Sand	(2.0-1.0 mm)	0.7	1.5					0.0	0.1
Coarse Sand	(1.0-0.5 mm)	5.1	5.3					0.1	0.2
Medium Sand	(0.5-0.25 mm)	12.3	14.3					0.3	0.3
Fine Sand	(0.25-0.10 mm)	23.7	29.2					6.7	7.2
Very Fine Sand	(0.10-0.05 mm)	17.1	14.9					50.9	40.3
Total Sand	(2.0-0.05 mm)	58.9	65.2	43.0	31.5	40.1	6.4	58.0	48.1
Silt	(0.05-0.002 mm)	27.3	18.2	31.4	37.7	36.2	76.7	37.8	45.7
Clay	(< 0.002 mm)	13.8	16.6	25.6	30.8	23.7	16.9	4.2	6.2
TEXTURAL CLASS (LAB.)		FSL	FSL	L	CL	L	SiL	VFSL	VFSL
BULK DENSITY	(g/cm^3)	1.61	1.64	1.59	1.67				
HYDRAULIC CONDUCTIVITY	(cm/hr)								
6th hr		0.36	1.62	2.24	0.76	0.41	0.41	7.42	1.62
24th hr		0.20	1.42	1.93	0.71	0.36	0.36	6.91	1.62
SETTLING VOLUME	(ml)	16	17	21	22	20	22	16	18
MOISTURE RETENTION	(percent)								
1/10 bar		24.3	18.4	23.2	27.2	28.6	31.3	12.7	19.5
1/3 bar		16.5	12.6	17.7	22.0	22.4	24.9	6.5	10.3
15 bar		6.1	6.4	10.1	10.4	9.9	7.3	2.6	3.5
SOIL REACTION-pH									
Paste									
1:5 H_2O		6.2	6.4	7.7	8.8	9.1	9.3	9.2	9.3
1:2 0.01 M $CaCl_2$		5.5	5.5	6.4	7.6	8.0	8.1	7.9	7.7
ORGANIC CARBON	(percent)								
AVAILABLE PHOSPHORUS	(ppm)								
$CaCO_3$ EQUIVALENT	(percent)								
GYPSUM REQUIREMENT	(me/100g)	+0.1	<0.1	-0.3	-0.8	-0.7	-0.4	-0.4	-0.1
SATURATION EXTRACT									
Saturation Percentage		31.0	26.4	42.1	41.0	37.5	39.8	33.7	33.1
EC_e @ 25°C	(mmhos/cm)	0.82	0.35	0.70	0.70	1.1	0.74	0.52	0.62
Ca^{++}	(me/l)	2.69	1.54	3.46	2.52	1.04	0.66	0.60	0.42
Mg^{++}	(me/l)	1.90	1.27	3.53	3.53	7.15	4.61	2.80	1.44
Na^+	(me/l)	0.37	0.40	0.47	0.56	2.38	2.60	2.03	4.78
K^+	(me/l)	0.68	0.26	0.20	0.17	0.14	0.13	0.12	0.14
CO_3^-	(me/l)	0.00	0.00	0.00	0.00	0.08	0.12	0.00	0.00
HCO_3^-	(me/l)	1.22	0.86	5.98	4.58	5.12	3.90	3.14	3.84
Cl^-	(me/l)	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SO_4^-	(me/l)	0.84	1.08	0.45	0.58	0.96	1.20	0.84	1.40
NO_3^-	(me/l)	2.42	0.63	0.18	0.66	3.55	2.39	1.21	1.13
SAR		0.2	0.3	0.2	0.3	1.2	1.6	1.6	5.0
Na	(me/100g)	0.01	0.01	0.02	0.02	0.09	0.10	0.07	0.16
Ca+Mg	(me/100g)	.14	.07	.30	.24	.31	.21	.11	.06
1:5 EXTRACT									
EC_5 @ 25°C	(mmhos/cm)	<0.1	<0.1	<0.1	<0.1	0.22	0.20	<0.1	<0.1
Ca+Mg	(me/100g)	0.5	0.5	1.3	1.2	1.4	1.1	0.8	0.8
EXCHANGEABLE SODIUM	(percent)	0.1	0.2	0.3	0.3	1.3	2.0	2.1	5.4
ACIDITY									
IN KCl exchange acidity									
Total	(me/100g)								
Al^{+++}	(me/100g)								
CATION EXCHANGE CAPACITY	(me/100g)	13.4	13.4	20.0	20.2	18.4	11.6	4.2	5.4
NaOAc@pH 8.2									
BORON	(mg/l)								

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Bureau of Reclamation

U.S. BUREAU OF RECLAMATION
POINT SITE LAND CHARACTERIZATION
(WITH DETERMINATIONS)

Master Site No. 4

Table 28

Study Area: Horse Nose Butte, North Dakota
Location. Sec. 15 Twp. 144N Range 94W
600'E, 1100'N of SW Cor. of NW¼, Dunn County
Climate: Semi-arid
Land Use: Pasture

Relief: Simple - strong convex slopes
Elevation: 2,310
Slope: Aspect: 11 percent
Vegetation: Western wheatgrass, Bluegrama & sweet-clover
Erosion: Moderate

Stoniness: None
Drainage: Well
Ground Water: None to 120 inches
Land Form: Sloping residual upland

Parent Material: Soft siltstone bedrock
Soil Series: San silt loam
Soil Classification: Fine-silty, mixed family of Typic Haploborolls
Profile Description By: M.R. Wright, M.Roningen Date: 10/22/75

LAB NO.	DEPTH (cm)	PROFILE DESCRIPTION
R453	0-15 Alp	Dark grayish brown (10YR 4/2) silt loam, very dark grayish brown (10YR 3/2) moist; granular structure; friable, slightly sticky, slightly plastic; many medium roots; abrupt smooth boundaries.
R454	15-28 B21	Grayish brown (2.5Y 5/2), light olive brown (2.5Y 5/4) crushed silt loam, dark grayish brown (2.5Y 4/2) moist; moderate medium prismatic structure; friable, slightly sticky, slightly plastic; common fine and medium roots; few very fine tubular pores; clear boundary.
R455	28-58 B3	Light yellowish brown (2.5Y 6/4) silt loam, olive brown (2.5Y 4/4) moist; moderate medium prismatic structure; friable, slightly sticky, slightly plastic; few fine and medium roots; few very fine tubular pores; lime masses in low part; clear boundaries.
R456	58-91 Clrca	Light brownish gray (2.5Y 6/2) soft weathered siltstone parting to silt loam; greyish brown (2.5Y 5/2) moist; strong coarse and medium platy structure; friable, slightly sticky, slightly plastic; few roots along horizontal planes and vertical cracks; many medium irregular threads of lime; violent effervescence; few fine tubular pores; gradual boundaries.
R457	91-165 C2r	Light brownish gray (2.5Y 6/2) soft weathered siltstone parting to loam; grayish brown (2.5Y 5/2) moist; few large distinct brownish yellow (10YR 6/6) mottles also few medium prominent brown or dark brown (7.5YR 4/4) mottles; strong coarse platy structure; friable, slightly sticky, slightly plastic; few roots along horizontal planes and vertical cracks; gradual boundaries.
R458	165-213 C3r	Light brownish gray (2.5Y 6/2) soft weathered siltstone parting to silty clay loam; grayish brown (2.5Y 5/2) moist; few large distinct pale yellow (2.5Y 7/2) mottles; strong coarse platy structure.
R459	213-244 C3r	Light gray (5Y 6/1) soft weathered siltstone parting to silty clay loam, grey (5Y 5/1) moist; upper 4 inches contains oxidized fibrous organic matter.
R460	244-305 C4r	Light gray (5Y 7/1) soft weathered siltstone parting to silty clay loam; light olive gray (5Y 6/2) moist; few small masses of gypsum.

LABORATORY DESCRIPTION

DETERMINATION		DATA							
LABORATORY NUMBER		R453	R454	R455	R456	R457	R458	R459	R460
DEPTH	(cm)	0-15	15-28	28-58	58-91	91-165	165-213	213-244	244-305
PARTICLE SIZE ANALYSIS	(percent)								
Very Coarse Sand	(2.0-1.0 mm)								
Coarse Sand	(1.0-0.5 mm)								
Medium Sand	(0.5-0.25 mm)								
Fine Sand	(0.25-0.10 mm)								
Very Fine Sand	(0.10-0.05 mm)								
Total Sand	(2.0-0.05 mm)	38.3	41.8	41.0	11.5	41.5	6.0	2.4	0.9
Silt	(0.05-0.002 mm)	39.7	35.4	38.9	68.2	40.3	73.4	44.1	50.5
Clay	(<0.002 mm)	22.0	22.8	20.1	20.3	18.2	20.6	53.5	48.6
TEXTURAL CLASS (LAB.)		L	L	L	SiL	L	SiL	SiC	SiC
BULK DENSITY	(g/cm^3)	1.48	1.45	1.51	1.63				
HYDRAULIC CONDUCTIVITY	(cm/hr)								
6th hr		0.61	1.62	2.03	0.61	1.52	0.15	0.05	<0.02
24th hr		0.56	1.52	2.03	0.61	1.52	0.20	0.05	0.05
SETTLING VOLUME	(ml)	23	23	23	24	30	32	37	39
MOISTURE RETENTION	(percent)								
1/10 bar		31.3	28.1	31.0	39.7	40.7	42.5	41.2	46.1
1/3 bar		21.6	19.7	21.0	27.1	26.3	36.4	35.4	36.8
15 bar		12.2	12.2	11.9	12.4	11.2	18.1	26.4	26.2
SOIL REACTION-pH									
Paste									
1:5 H_2O		7.3	7.4	7.6	8.1	8.4	7.8	7.0	6.9
1:2 0.01 M $CaCl_2$		6.4	6.6	7.6	8.1	8.2	7.6	5.4	5.3
ORGANIC CARBON	(percent)								
AVAILABLE PHOSPHORUS	(ppm)								
$CaCO_3$ EQUIVALENT	(percent)								
GYPSUM REQUIREMENT	(me/100g)	+0.3	+0.1	-0.3	-0.4	+0.8	-13	-5.8	-5.0
SATURATION EXTRACT									
Saturation Percentage		44.3	45.8	45.3	52.0	51.7	64.4	64.3	64.9
EC_e @ 25°C	(mmhos/cm)	0.72	0.32	0.52	0.72	0.76	7.5	8.2	6.3
Ca^{++}	(me/l)	2.41	1.59	2.47	1.48	0.49	24.15	22.67	16.69
Mg^{++}	(me/l)	1.72	1.18	3.71	3.44	1.99	80.60	81.61	67.66
Na^+	(me/l)	0.70	0.79	0.75	2.13	5.74	26.09	23.04	18.26
K^+	(me/l)	0.87	0.16	0.14	0.11	0.16	1.39	1.33	1.22
CO_3^-	(me/l)	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00
HCO_3^-	(me/l)	3.60	2.20	5.82	5.88	5.28	0.66	1.40	0.62
Cl^-	(me/l)	0.00	0.00	0.02	0.02	0.06	1.64	1.80	1.34
SO_4^-	(me/l)	0.85	0.76	0.50	0.32	1.55	130.80	125.60	102.80
NO_3^-	(me/l)	0.13	0.14	0.07	0.12	0.44	0.23	0.35	0.35
SAR		0.5	0.7	0.4	1.4	5.2	3.6	3.2	2.8
Na	(me/100g)	0.03	0.04	0.03	0.11	0.30	1.68	1.48	1.19
Ca+Mg	(me/100g)	.19	.12	.28	.26	.13	7.75	13.42	5.47
1:5 EXTRACT									
EC_5 @ 25°C	(mmhos/cm)	0.19	0.12	0.30	0.16	0.25	3.4	1.6	1.6
Ca+Mg	(me/100g)	0.8	0.6	0.7	1.1	0.7	23	7.2	7.2
EXCHANGEABLE SODIUM	(percent)	0.4	0.5	0.4	0.6	5.3	3.5	3.3	4.0
ACIDITY									
IN KCl exchange acidity									
Total	(me/100g)								
Al^{+++}	(me/100g)								
CATION EXCHANGE CAPACITY	(me/100g)	22.4	24.0	24.0	47.2	20.2	15.8	26.6	33.4
NaOAc@pH 8.2									
BORON	(mg/l)								

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Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Master Site No. 5

Study Area: Horse Nose Butte, North Dakota
Location. Sec. 12 Twp. 144N Range 94W
1650'E, 1500'N SW Corner, Dunn County
Climate: Semi-arid
Land Use: Cultivated

Relief: Simple, convex
Elevation: 2,280'
Slope: Aspect: 8 percent
Vegetation: Fallow, small grains
Erosion: Slight

Stoniness: None
Drainage: Well
Ground Water: None to 120 inches
Land Form: Gently sloping uplands

Parent Material: Residuum from soft siltstone
Soil Series: Amor loam
Soil Classification: Fine-loamy, mixed family of Typic Haploborolls
Profile Description By: M.R. Wright, W. Forest Date: 11/11/75

LAB NO.	DEPTH (cm)	PROFILE DESCRIPTION
R658	0-18 Ap	Dark grayish brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; weak medium subangular blocky structure parting to weak medium and fine granular structure; hard, very friable, slightly sticky and slightly plastic; many fine and medium roots; few very fine tubular pores; abrupt smooth boundary.
R659	18-38 B21	Brown to dark brown (10YR 4/3) loam, dark brown (10YR 3/3) moist; weak medium prismatic structure parting to weak medium subangular blocky structure; hard, friable, slightly sticky, slightly plastic; many fine and medium roots; few very fine tubular pores; clear wavy boundary.
R660	38-58 1/ B22	Light olive brown (2.5Y 5/4) loam, dark grayish brown (2.5Y 4/2) moist; few fine distinct yellowish brown mottles; moderate medium prismatic structure parting to strong fine and medium blocky structure; very hard, firm, slightly sticky, slightly plastic; many roots; common fine tubular pores; continuous thick clay films on faces of peds; clear wavy boundary.
R661	58-84 Cca	Light brownish gray (2.5Y 6/2) silty clay loam, dark grayish brown crushed (2.5Y 4/2) moist; moderate medium prismatic structure; hard, firm, slightly sticky, slightly plastic; violent effervescence, many soft masses of lime; few medium and fine roots; few fine tubular pores; continuous moderately thick clay films on faces of peds; gradual boundary.
R662	84-127 C1r	Mixed, light brownish gray and light olive brown (2.5Y 6/2 and 5/4) stratified soft sandstone, dark grayish brown and olive brown (2.5Y 4/2 and 4/4) moist; few medium distinct dark reddish brown mottles (2.5YR 3/4); friable; few medium and fine roots; slight effervescence; gradual boundary.
R663	127-229 C2r	Light brownish gray (2.5Y 6/2) stratified soft siltstone; dark grayish brown (2.5Y 4/2) moist; weak medium platy structure; friable; few medium roots; gradual boundary.
R664	229-305 C3r	Light brownish gray (2.5Y 6/2) soft siltstone; dark grayish brown (2.5Y 4/2) moist; weak medium platy structure.

1/ NOTE: A discontinuous layer of very dark grayish brown (2.5Y 3/2) loam, very dark brown (10YR 2/2) moist; occurs at about the 15 inch depth and tongues into the B22 horizon. (Not sampled)

LABORATORY DESCRIPTION

DETERMINATION	Units	R658	R659	R660	R661	R662	R663	R664
LABORATORY NUMBER		R658	R659	R660	R661	R662	R663	R664
DEPTH	(cm)	0-18	18-38	38-58	58-84	84-127	127-229	229-305
PARTICLE SIZE ANALYSIS	(percent)							
Very Coarse Sand	(2.0-1.0 mm)							
Coarse Sand	(1.0-0.5 mm)							
Medium Sand	(0.5-0.25 mm)							
Fine Sand	(0.25-0.10 mm)							
Very Fine Sand	(0.10-0.05 mm)							
Total Sand	(2.0-0.05 mm)	47.6	42.9	29.0	7.5	24.5	4.2	1.3
Silt	(0.05-0.002 mm)	35.8	38.1	45.8	64.7	53.7	71.2	74.0
Clay	(<0.002 mm)	16.6	19.0	25.2	27.8	21.8	24.6	24.7
TEXTURAL CLASS (LAB.)		L	L	L	SiCL	SiL	SiL	SiL
BULK DENSITY	(g/cm^3)	1.41	1.60	1.53	1.55	1.57	1.50	
HYDRAULIC CONDUCTIVITY	(cm/hr)							
6^{th} hr		0.10	0.25	0.10	*	*	0.08	*
24^{th} hr		0.15	0.30	0.15	<0.02	*	0.10	0.02
SETTLING VOLUME	(ml)	18	19	23	42	155	15	82
MOISTURE RETENTION	(percent)							
1/10 bar		25.1	25.3	33.8	37.1	42.3	39.3	42.0
1/3 bar		16.7	18.4	26.3	31.5	39.2	32.6	36.5
15 bar		8.2	9.2	13.6	15.0	18.7	15.7	22.0
SOIL REACTION-pH								
Paste								
1:5 H_2O		7.0	7.0	7.4	9.2	9.6	8.3	8.9
1:2 0.01 M $CaCl_2$		5.8	6.0	6.3	7.7	8.1	8.0	7.8
ORGANIC CARBON	(percent)							
AVAILABLE PHOSPHORUS	(ppm)							
$CaCO_3$ EQUIVALENT	(percent)							
GYPSUM REQUIREMENT	(me/100g)	+0.3	+0.1	+1.0	+0.7	+2.4	-7.0	+0.4
SATURATION EXTRACT								
Saturation Percentage		32.7	34.1	47.3	61.9	83.9	70.9	81.1
EC_e @ 25°C	(mmhos/cm)	0.39	0.38	0.44	0.67	1.0	7.1	3.9
Ca^{++}	(me/l)	1.85	1.76	0.69	0.27	0.22	22.29	4.56
Mg^{++}	(me/l)	1.27	1.45	0.87	0.62	0.45	36.18	9.68
Na^+	(me/l)	0.35	0.58	3.62	6.33	8.94	40.08	28.12
K^+	(me/l)	0.55	0.17	0.11	0.09	0.09	0.79	0.57
CO_3^-	(me/l)	0.00	0.00	0.00	0.24	0.16	0.00	0.00
HCO_3^-	(me/l)	2.08	2.28	3.56	5.24	4.32	2.20	2.28
Cl^-	(me/l)	0.44	0.08	0.46	0.28	1.38	3.18	1.98
SO_4^-	(me/l)	0.96	0.88	0.93	1.20	4.00	96.80	38.20
NO_3^-	(me/l)	0.05	0.18	0.27	0.50	0.45	0.97	3.31
SAR		0.3	0.5	4.1	9.5	15.0	7.4	11.0
Na	(me/100g)	0.01	0.02	0.17	0.39	0.75	2.84	2.28
Ca+Mg	(me/100g)	.10	.11	.07	.06	.06	4.15	1.16
1:5 EXTRACT								
EC_5 @ 25°C	(mmhos/cm)	0.11	0.11	0.14	0.30	0.44	2.2	0.86
Ca+Mg	(me/100g)	0.4	0.4	0.5	1.2	0.4	9.5	2.5
EXCHANGEABLE SODIUM	(percent)	0.4	0.5	0.4	7.8	15.0	8.9	10.0
ACIDITY								
IN KCl exchange acidity								
Total	(me/100g)							
Al^{+++}	(me/100g)							
CATION EXCHANGE CAPACITY	(me/100g)	15.8	17.4	22.8	25.0	22.8	24.8	27.6
NaOAc@pH 8.2								
BORON	(mg/l)							

* Denotes that no water was transmitted through soil column prior to and during specified testing period.

GPO 833-796

Table 29

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Bureau of Reclamation

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Master Sits No. 6

Study Area: Horse Nose Butte, North Dakota
Location. Sec. 12 Twp. 144N Range 94W
800'E, 850'N of SW Corner, Dunn County
Climate: Semi-arid
Land Use: Pasture

Relief: Simple - 10 inches micro-relief
Elevation: 2,260'
Slope: Aspect: Nearly level
Vegetation: Western Wheatgrass, Junegrass, Cacti, Lichens
Erosion: Slight

Stoniness: None
Drainage: Moderately well
Ground Water: None to 120 inches
Land Form: Nearly level upland plains, concave swales

Parent Material: Residuum from shale
Soil Series: Rhoades loam
Soil Classification: Fine, montmorillonitic family of Leptic Natriborolls
Profile Description By: M.R. Wright, W. Forest Date: 11/13/75

LAB NO.	DEPTH (cm)	PROFILE DESCRIPTION
R665	0-8 A2	Grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; weak crumb structure; slightly hard, friable, slightly sticky, slightly plastic; many very fine and fine roots; abrupt irregular boundary.
R666	8-25 B2t	Dark grayish brown (2.5Y 4/2) crushed, grayish brown (10YR 5/2) coated, silty clay loam, very dark grayish brown (2.5Y 3/2) moist; strong medium columnar structure parting to strong medium and fine subangular blocky structure; very hard, firm, slightly sticky, slightly plastic; few very fine roots; common moderately thick clay films on faces of peds; clear wavy boundary.
R667	25-74 Cca	Grayish brown (2.5Y 5/2) silty clay loam, olive gray (5Y 4/2) moist; strong medium and fine subangular blocky structure; very hard, firm, sticky and plastic; strongly effervescence; common fine soft masses of lime; salt crystals; few fine roots; few pores; gradual wavy boundary.
R668	74-150 C1	Light olive brown (2.5Y 5/4) silty clay loam, olive brown (2.5Y 4/4) moist; few pockets of gravelly loam and boulders; very hard, firm, sticky and plastic; very slight; effervescence in small areas of salt crystals; gradual boundary.
R669	150-213 C2r	Light gray (5Y 6/1) soft shaly sedimentary bedrock, olive gray (5Y 4/2) moist; moderate medium platy structure; gradual boundary
R670	213-305 C3r	Multi-colored mottled soft shaly bedrock with some hard sandstone.

LABORATORY DESCRIPTION

DETERMINATION		R665	R666	R667	R668	R669	R670
LABORATORY NUMBER		R665	R666	R667	R668	R669	R670
DEPTH	(cm)	0-8	8-25	25-74	74-150	150-213	213-305
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)						
Coarse Sand	(1.0-0.5 mm)						
Medium Sand	(0.5-0.25 mm)						
Fine Sand	(0.25-0.10 mm)						
Very Fine Sand	(0.10-0.05 mm)						
Total Sand	(2.0-0.05 mm)	31.9	15.6	12.3	1.3	2.2	10.8
Silt	(0.05-0.002 mm)	56.3	49.6	46.3	25.4	67.8	62.8
Clay	(<0.002 mm)	11.8	34.8	41.4	73.3	30.0	26.4
TEXTURAL CLASS (LAB.)		SiL	SiCL	SiC	C	SiCL	SiL
BULK DENSITY	(g/cm^3)	1.48	1.51	1.70	1.58	1.57	1.66
HYDRAULIC CONDUCTIVITY	(cm / hr)						
6th hr		.08	.05	*	*	*	*
24th hr		.08	.20	<0.02	*	<0.02	<0.02
SETTLING VOLUME	(ml)	20	40	37	85	80	355
MOISTURE RETENTION	(percent)						
1/10 bar		29.7	41.1	35.3	52.1	42.3	38.1
1/3 bar		20.8	35.1	30.1	44.2	36.4	30.3
15 bar		6.8	18.1	16.1	30.4	22.7	17.7
SOIL REACTION-pH							
Paste							
1:5 H_2O		7.4	8.9	8.7	7.6	7.9	8.5
1:2 0.01 M $CaCl_2$		5.9	8.1	8.1	7.6	7.7	7.9
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	+0.6	+3.6	-4.3	-10.0	-1.7	-2.0
SATURATION EXTRACT							
Saturation Percentage		36.3	69.6	63.8	112.1	74.0	84.2
EC_e @ 25°C	(mmhos/cm)	0.72	3.8	11.0	9.6	9.7	7.6
Ca^{++}	(me/l)	0.68	1.70	19.49	19.21	18.94	17.84
Mg^{++}	(me/l)	0.58	5.07	50.21	40.25	34.83	22.16
Na^{+}	(me/l)	5.63	33.96	89.57	80.22	83.26	62.39
K^{+}	(me/l)	0.20	0.19	1.28	1.28	1.41	1.15
CO_3^{-}	(me/l)	0.00	0.56	0.00	0.00	0.00	0.16
HCO_3^{-}	(me/l)	2.28	7.96	3.36	2.12	1.84	1.64
Cl^{-}	(me/l)	1.06	1.14	1.22	0.40	0.28	0.04
SO_4^{-}	(me/l)	3.60	32.20	156.00	137.00	136.00	100.00
NO_3^{-}	(me/l)	0.14	0.27	0.17	0.24	0.27	0.26
SAR		7.1	18.0	15.0	15.0	16.0	14.0
Na	(me/100g)	0.20	2.36	5.71	8.99	6.16	5.25
Ca+Mg	(me/100g)	.04	.47	4.44		3.98	3.37
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)	0.14	0.86	3.8	4.6	3.8	1.7
Ca+Mg	(me/100g)	0.8	1.4	9.6	20.0	7.1	4.7
EXCHANGEABLE SODIUM	(percent)	7.0	17.0	10.0	15.0	14.0	10.0
ACIDITY							
IN KCl exchange acidity							
Total	(me/100g)						
Al^{+++}	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	12.8	35.2	42.2	46.6	31.4	26.6
NaOAc@pH 8.2							
BORON	(mg/l)						

* Denotes that no water was transmitted through soil column prior to and during specified testing period.

Table 30

REPORT OF MASTER SITE SOIL ANALYSES
US BUREAU OF RECLAMATION
MISSOURI SOURIS PROJECTS OFFICE
BISMARCK, NORTH DAKOTA

Table 33

SOIL ANALYSES - BEDROCK SAMPLES

DATE RECEIVED: ______

AREA: *Horse nose Butte* SECTION: ______ TOWNSHIP: ______ RANGE: ______ INVESTIGATOR: *Herman DuPree* SOIL TYPE: ______ LAND CLASS: ______ DATE REPORTED: ______

Lab Number	Boring Number	Depth in Feet	Field Texture	% Sand	V.Co 2.0-1.0	Co 1.0-0.5	Med 0.5-0.25	Fine 0.25-0.10	V.Fine 0.10-0.05	% Silt	% 2µ Clay	Lab Text	Moisture Retention % Pressure in Bars 0.10	0.33	15	Hyd Cond in/hrs ½ Hr	24 Hr	Sat Vol ml	pH @ 25 H_2O 1:5	CaCl₂ Paste	EC×10³ @ 25°C	ECe×10³ @ 25°C
1	DH 75 101	0-5.0											34.9	23.5	12.1	0.32	0.30	25	7.7	6.6		
2		5.0-15.0											47.1	40.5	28.2	0.01	<0.01	30	4.1	3.5		
3		15.0-31.7		66.5	0.0	3.6	17.0	27.7	18.2	21.4	12.1	FSL	23.9	15.9	7.9	0.60	0.52	23	4.6	3.9	1.3	8.0
4		41.1-70.2		27.8						46.8	25.4	L	46.4	39.2	29.4	0.00	0.00	110	9.3	7.9	0.54	2.4
5		70.9-88.7		52.8						21.4	25.8	SCL	51.1	43.3	32.7	0.00	0.00	190	9.5	8.2	0.60	2.1
6		87.3-143.2		33.8						47.0	19.2	L	45.6	39.3	31.6	0.00	0.00	120	9.7	8.4	0.60	2.1
7		176.0-193.6		4.3						50.9	44.8	SiC	48.7	40.2	26.5	0.00	0.00	155	9.0	7.8	0.72	2.8
8		193.6-202.5		3.1						56.6	40.3	SiC	49.3	39.1	24.7	0.00	0.00	80	9.8	8.4	0.66	1.9
9		207.5-212.1		36.1						45.3	18.6	L	46.2	37.3	28.4	0.00	0.00	200	9.6	8.2	0.50	1.6
1	DH 75 102	0.0-5.2											43.8	36.9	5.9	0.31	0.30	21	7.4	6.7		
2		5.2-30.3		83.9	0.1	32.4	30.5	17.0	3.9	9.1	7.0	LFS	22.9	15.5	3.0	1.72	1.40	19	8.0	7.1	0.60	4.6
3		30.3-44.8		62.6	0.3	0.4	0.5	32.7	28.7	19.4	18.0	FSL	41.3	29.5	10.5	0.30	0.28	25	5.0	4.6	1.3	7.7
4		57.3-69.6		31.2						47.2	21.6	L			11.4	0.09	0.04	27	8.2	7.7	0.62	3.5
5		69.6-85.4		4.1						69.0	26.7	SiL	33.1	22.5	19.2	0.00	<0.01	30	8.5	7.7	0.62	2.8
6		85.6-101.3		63.9	0.3	0.8	7.3	40.5	14.0	26.7	9.4	FSL	21.5	16.2	4.8	0.28	0.24	22	8.2	7.9	0.44	3.2
7		114.9-137.9		1.2						57.8	41.0	SiC		35.9	24.5	0.00	0.00	200	9.2	8.2	0.52	2.1
8		132.4-141.2		38.0						51.8	10.2	SiL	29.3	17.8	4.7	0.00	0.00	35	9.2	7.7	0.40	2.8
9		178.1-201.7		1.4						58.7	29.9	SiCL	46.1	39.3	23.7	0.00	0.00	55	9.6	8.4	0.72	2.0
10		201.7-208.7		41.0						39.9	19.1	L	46.7	42.5	25.8	0.00	0.00	60	9.9	8.9	0.86	1.8
1	DH 75 103	0.0-5.0											24.0	17.0	7.5	0.38	0.30	20	7.8	6.9		
2		5.0-21.7		77.4	0.0	16.7	30.6	23.7	6.4	12.9	9.7	SL	13.1	10.0	3.8	0.68	0.60	20	6.7	5.5	0.14	1.1
3		26.0-47.7		71.9	0.2	0.3	2.0	46.4	23.0	16.7	11.4	FSL	22.8	17.2	7.5	1.36	1.20	23	5.2	4.5	0.40	2.7
4		47.7-58.4		1.5						68.3	30.2	SiCL	47.8	40.2	28.1	0.00	0.00	37	8.4	7.8	0.40	1.4
5		62.3-75.9		17.8						57.3	24.9	SiL	45.0	37.5	21.3	0.00	0.00	50	8.9	8.0	0.36	1.4
6		75.9-82.0		56.1						22.6	21.3	SCL	41.0	35.2	25.7	0.00	0.00	80	9.7	8.7	0.36	1.3
7		87.8-106.4		6.5						63.3	30.2	SiCL	70.8	48.2	38.5	0.00	0.00	350	9.6	8.6	0.62	1.7
8		108.2-123.7		10.9						63.2	25.9	SiL	59.5	42.1	37.9	0.00	0.00	225	9.8	8.7	0.72	2.0
9		123.7-150.4		63.2	0.3	1.4	7.5	28.5	25.5	21.2	15.6	FSL	42.6	35.5	22.9	0.00	0.00	120	9.9	8.7	0.60	1.7
10		154.7-169.6		6.9						40.6	52.5	SiC	47.8	39.9	22.5	0.00	0.00	135	9.0	7.9	0.52	2.1
11		185.1-202.8		9.9						37.5	52.6	C	59.2	41.7	23.0	0.00	0.00	170	9.0	8.1	0.50	1.6
1	DH 75 104	[illegible]-16.5		[illegible]						48.4	24.6	L	31.5	26.4	11.3	0.07	0.09	29	8.4	7.7	1.3	5.0
2		16.5-[illegible]		22.3						49.4	28.3	CL	37.6	32.1	12.8	0.03	0.04	32	7.8	7.0	1.9	4.1
3		36.[illegible]-46.5											16.9	12.1	7.1	0.60	0.68	19	7.4	6.9		
4		50.0-80.8		0.9						63.9	35.2	SiCL	39.2	28.6	17.9	0.00	0.02	50	8.2	7.1	0.52	2.5
5		99.4-114.0		1.7						53.8	44.5	SiC	68.5	48.7	28.6	0.00	0.00	200	9.5	8.1	0.60	1.4
6		114.0-118.4											78.8	54.6	47.7	0.00	0.00	280	9.8	8.5		
7		118.4-123.5											76.5	55.9	43.3	0.00	0.00	260	9.8	8.7		
8		123.5-133.5		64.6	0.1	0.9	16.3	24.9	22.4	20.7	14.7	FSL		40.8	25.0	0.00	0.00	80	9.7	8.7	0.52	2.1
1	DH 75 105	0.0-12.4											15.5	8.5	4.5	1.72	1.52	18	7.2	6.6		
2		12.4-31.8		32.3						30.1	27.6	CL		41.7	14.6	[illegible]	0.23	18	7.9	7.4	1.7	3.4
3		33.8-54.9		16.9						56.0	27.1	SiCL	41.6	30.2	18.1	0.08	0.04	25	8.7	8.0	1.4	4.8
4		56.0-70.1		22.3						50.4	27.3	CL	43.0	27.7	17.1	0.01	0.01	30	9.0	7.9	0.68	2.5
5		77.3-80.9											64.1	49.9	26.7	0.00	0.00	300	8.7	7.8		
6		103.5-133.6											70.9	49.8	22.7	0.00	0.00	220	9.6	8.6		
1	DH 75 106	20.0-22.3											23.9	19.4	7.5	0.06	0.06	27	4.8	4.2		
2		22.7-34.6		27.1						56.4	27.5	CL	44.9	30.0	16.9	0.01	0.01	28	7.9	7.1	0.62	1.8
3		34.6-44.9		56.6						22.4	21.0	SCL	38.5	23.6	11.2	0.14	0.12	23	8.6	8.1	0.36	1.3
4		57.3-75.7		65.2						14.8	20.0	SCL	33.8	22.6	10.5	0.24	0.23	25	9.0	8.2	0.39	1.9
5		78.2-81.3											53.3		26.0	0.00	0.00	45	9.0	7.9		
6		82.2-98.3		68.2	0.1	0.2	0.2	16.2	45.5	18.8	19.0	VFSL	40.4	29.9	23.3	0.00	0.00	100	9.6	8.7	0.52	1.5
7		98.3-121.6		8.5						56.0	35.5	SiCL	69.3	49.8	36.9	0.00	0.00	280	9.6	8.5	0.70	1.6
8		125.1-128.6											116.3	89.4	30.2	0.00	0.00	450	9.3	8.4		
9		150.7-165.3		6.2						63.1	30.7	SiCL	65.3		35.8	0.00	0.00	100	9.6	8.8	0.72	1.6
10		165.1-180.5		44.5						32.2	22.7	L	53.7		33.3	0.00	0.00	125	9.7	9.1	0.74	1.6
1	DH 75 107	0.7-11.8														0.02	0.01	39	8.0	7.8		
2		11.8-37.6		22.5						47.1	30.4	CL	43.4		20.2	0.00	0.00	60	8.1	7.9	1.9	3.2
3		45.4-56.0		3.4						45.3	51.3	SiC	65.9	43.7	29.3	0.00	0.00	290	8.7	8.2	1.1	3.5
4		73.8-93.8		12.7						55.0	32.3	SiCL	60.0		34.1	0.00	0.00	160	9.4	8.5	0.80	1.3
5		93.8-103.8		73.0	0.0	0.2	3.6	57.1	12.1	10.0	17.0	FSL			30.9	0.00	0.00	90	9.7	9.2	0.68	1.2
1	DH 75 [illegible]	0-8.0														0.14	0.10	25	8.1			
2		8.0-20.3		2.5						59.1	38.4	SiCL	41.1		22.9	0.00	0.01				1.5	5.2
3		21.7-26.0											43.6		17.6	0.00	<0.01	31	8.5	7.9		
4		26.0-31.6 / 31.6-34.1		41.0						40.8	18.2	L		34.9	10.9	0.05	0.03	14	8.9	8.2	0.44	1.8
5		43.3-58.4		2.9						57.3	39.8	SiCL	39.0		25.0	0.00	0.00	200	9.2	8.3	0.60	2.0
6		76.2-98.0		2.9						52.9	44.2	SiC	68.4	45.1	29.9	0.00	0.00	260	9.4	8.3	0.50	1.7
7		98.0-103.5		30.4						52.7	16.9	SiL	53.5	35.4	27.9	0.00	0.00	170	9.8	8.7	0.52	1.6

Lab Number	Boring Number	Saturation Extract Cations, me/l Ca	Mg	Na	K	Σ Cations	Anions, me/l CO_3	HCO_3	Cl	SO_4	Σ Anions	SAR	SP	me/100g Ca	Mg	Na	K	Total Extractable Cations me/100g Ca	Mg	Na	K	Exchangeable Cations me/100g Ca	Mg	Na	K	ESP	% Base Sat	Gyp me/100g	Gyp Req me/100g	% $CaCO_3$ Equiv.	% Org-C	% Field Mois. Cap	Bulk Density g/cm³	Field Hyd Cond. in/hr	Field Infiltration in/hr	CEC me/100g
1	DH 75 101																																			
2																																				
3		21.41	70.56	32.49	0.83	125.29	0.00	0.20	0.68	125.0	2.98	4.9	40.3	0.86	2.84	1.33	0.03			1.95	0.28			8.62	0.35	42		5.9	-4.2							14.9
4		0.82	1.27	23.19	0.61	25.67	0.80	7.16	0.80	14.6	0.11	23	82.8	0.07	0.11	1.91	0.04			7.66	0.64			5.25	0.60	23		0.4	+5.0							23.1
5		0.38	0.27	21.78	0.34	22.77	1.44	9.00	0.32	10.30	0.00	38	98.2	0.03	0.02	1.92	0.03			19.17	0.73			12.25	0.70	43		0.5	+12							28.3
6		0.49	0.81	20.09	0.27	21.66	0.88	7.32	0.04	11.60	0.00	25	82.6	0.04	0.07	1.66	0.02			8.28	0.48			6.62	0.46	37		0.3	+6.4							17.7
7		5.24	5.97	19.00	1.05	31.26	0.00	4.24	0.02	25.60	0.03	8.0	61.3	0.33	0.37	1.18	0.07			9.91	0.79			8.73	0.72	30			+7.4							28.9
8		0.27	0.27	19.35	0.34	20.23	1.12	9.64	0.00	7.80	0.00	37	84.1	0.02	0.02	1.63	0.03			8.75	0.71			7.12	0.69	21		0.4	+7.5							33.2
9		0.32	0.09	16.22	0.13	16.76	0.96	7.92	0.02	6.60	0.07	41	78.8	0.02	<0.01	1.28	0.02			8.21	0.50			6.93	0.48	39		0.4	+7.0							17.6
1	DH 75 102																																			
2		21.51	29.11	17.04	0.30	67.96	0.00	2.64	1.16	58.70	0.14	3.4	24.4	0.52	0.71	0.42	0.01			0.68	0.16			0.26	0.15	5.0		2.4	-2.2							5.2
3		18.11	92.27	16.39	1.21	127.98	0.00	0.40	1.24	121.00	3.87	2.2	47.8	0.87	4.41	0.78	0.06			1.10	0.38			0.32	0.32	14		7.4	-6.6							23.7
4		11.93	14.06	17.96	1.27	45.22	0.00	3.80	0.60	38.70	3.87	5.0	51.9	0.62	0.73	0.93	0.07			1.73	0.46			0.80	0.39	41		1.7	-0.3							19.4
5		0.88	1.00	28.78	0.52	31.18	0.72	8.56	0.00	18.90	0.10	30	~~64.6~~	~~0.26~~	~~0.06~~	~~1.86~~	0.05			3.04	0.69			1.18 (~~0.48~~)	0.66	42		1.1	+0.4							25.0
6		4.78	5.61	25.22	0.97	36.58	0.00	3.12	0.44	31.45	0.24	11	38.8	0.19	0.22	0.98	0.04			1.70	0.36			0.72	0.32	42		0.7	+0.2							7.8
7		0.49	0.36	21.78	0.48	23.11	0.56	6.00	0.00	14.60	0.20	33	82.9	0.04	0.03	1.81	0.04			7.91	0.75			5.60	0.71	18		0.4	+5.5							31.5
8		1.26	1.34	28.09	0.70	31.59	0.00	8.20	0.48	22.00	0.03	24	34.2	0.04	0.05	0.96	0.02			2.19	0.34			1.23	0.32	17		0.6	+1.6							7.1
9		0.49	0.45	20.65	0.41	22.00	0.72	7.48	—	13.00	0.07	31	71.9	0.04	0.03	1.53	0.03			8.68	0.88			7.15	0.85	26		0.2	+7.8							27.5
10		0.05	0.45	20.13	0.29	20.92	1.12	8.92	0.16	8.60	0.15	40	27.1	0.00	0.03	0.55	0.01			9.40	0.61			8.85	0.60	47		1.4	+7.4							19.0
1	DH 75 103																																			
2		3.57	3.35	3.87	0.20	10.99	0.00	0.56	0.48	9.60	0.73	2.1	23.2	0.08	0.08	0.04	<0.01			0.23	0.16			0.14	0.16	2.5		0.4	-0.1							5.7
3		15.09	16.10	4.57	0.60	36.36	0.00	1.80	—	34.55	0.80	1.2	38.2	0.58	0.62	0.17	0.02			0.41	0.34			0.24	0.32	1.3		1.5	-1.2							10.4
4		2.86	6.33	6.43	1.12	16.73	0.00	4.92	0.16	9.10	0.03	30	68.4	0.19	0.43	0.44	0.08			1.17	0.88			0.72	0.80	1.7		1.0	+0.3							43.7
5		0.38	1.36	13.35	0.60	15.69	0.32	5.64	0.74	7.80	0.05	14	71.2	0.03	0.1	1.06	0.05			4.30	0.81			3.24	0.76	13		0.4	+4.4							24.7
6		0.05	0.34	14.23	0.25	14.77	0.40	5.48	0.30	6.20	0.10	25	60.6	<0.01	0.03	0.92	0.02			8.31	0.68			7.39	0.66	29		0.4	+7.3							26.7
7		0.11	0.90	18.04	0.33	19.38	0.56	9.00	0.08	7.40	—	26	37.4	<0.01	0.03	0.67	<0.01			10.63	0.67			10.03	0.67	38		0.4	+1.0							26.7
8		0.11	0.63	20.70	0.29	21.73	0.64	8.72	0.00	18.20	0.15	35	10.9	<0.01	0.01	0.23	<0.01			9.37	0.55			9.14	0.55	37		0.6	+8.5							21.2
9		0.22	0.18	18.30	0.25	18.95	1.36	7.76	0.00	8.40	0.08	41	78.5	<0.01	0.01	1.44	0.02			7.42	0.41			5.98	0.39	37		0.3	+6.1							16.3
10		0.82	1.00	19.87	0.56	22.25	0.16	5.32	0.00	15.40	0.05	21	82.3	0.07	0.08	1.64	0.06			6.17	0.72			4.53	0.67	16		0.5	+4.7							43.2
11		0.38	0.36	16.57	0.39	17.91	1.04	7.84	0.00	7.40	0.08	28	97.5	0.04	0.04	1.64	0.04			8.27	0.84			6.63	0.80	24		0.4	+2.0							27.5
1	DH 75 104	24.15	21.16	25.87	0.46	71.64	0.00	2.00	0.74	67.00	0.04	5.4	48.0	1.16	1.02	1.24	0.02			2.57	0.42			1.33	0.40	69		6.3	-2.0							19.2
2		25.9[illegible]	13.66	18.43	0.70	58.74	0.00	3.32	0.14	52.80	0.04	4.1	59.1	1.53	0.81	1.08	0.04			2.25	0.52			1.16	0.48	7.4		[illegible]	-7.9							34.3
3																																				
4		1.81	2.08	22.57	0.77	27.23	0.24	5.08	0.00	20.09	0.03	16	61.6	0.11	0.13	1.39	0.05			3.46	0.55			2.07	0.50	7.7		0.3	+1.7							27.0
5		0.27	0.18	14.26	0.26	14.97	0.64	6.80	0.06	6.60	0.13	28	112.	0.03	0.02	1.60	0.03			10.00	0.79			8.40	0.74	25		0.2	+9.2							33.8
6																																				
7																																				
8		0.22	0.27	22.65	0.32	23.46	1.44	11.68	0.24	9.00	0.02	45	63.9	0.01	0.02	1.45	0.02			7.60	0.49			6.15	0.49	39		0.2	+6.0							15.7
1	DH 75 105																																			
2		27.28	13.66	7.83	0.41	49.18	0.00	1.88	1.02	45.60	0.04	1.7	50.1	1.37	0.68	0.39	0.02			0.72	0.46			0.33	0.43	1.4		4.4	-0.2							24.1
3		25.36	13.39	24.83	1.69	65.27	0.00	3.80	0.44	61.20	0.04	5.6	59.7	1.51	0.80	1.48	0.10			2.82	0.67			1.34	0.52	7.5		4.5	-1.4							17.9
4		1.48	1.36	23.57	0.73	27.14	0.24	8.24	0.02	17.60	0.04	20	61.5	0.09	0.08	1.45	0.04			4.79	0.61			3.34	0.57	[illegible]		0.4	+3.4							15.0
5																																				
6																																				
1	DH 75 106																																			
2		8.01	7.78	3.83	0.79	20.41	0.00	3.16	0.00	17.45	0.04	1.4	61.2	0.49	0.48	0.23	0.05			0.96	0.55			0.73	0.50	36		1.8	-0.4							20.0
3		3.90	4.52	4.09	0.65	13.16	0.00	2.96	0.14	10.10	0.03	2.0	50.3	0.20	0.23	0.21	0.03			0.39	0.41			0.38	0.38	19		0.9								20.4
4		2.42	3.26	13.00	0.71	19.39	0.00	3.88	0.26	14.50	0.03	7.7	47.3	0.11	0.15	0.61	0.03			2.15	0.48			1.54	0.45	76		0.4	+2.0							20.2
5																																				
6		0.16	0.09	15.17	0.27	15.69	0.64	6.60	0.24	7.15	0.06	39	40.5	0.01	<0.01	0.61	0.01			7.34	0.52			6.73	0.51	35		0.3	+7.2							19.5
7		0.27	0.09	16.56	0.24	17.16	0.56	7.84	0.00	7.40	0.06	37	87.7	0.02	0.01	1.45	0.02			11.46	0.31			10.01	0.49	55		0.4	+10							18.3
8																																				
9		0.16	0.09	17.26	0.26	17.77	1.68	8.88	0.04	6.10	0.04	45	93.0	0.01	0.01	1.61	0.02			13.53	0.95			11.92	0.93	63		0.5	+11.5							18.9
10		0.05	0.09	16.83	0.23	17.20	0.80	8.72	0.00	6.50	0.04	75	77.8	<0.01	0.01	1.31	0.02			11.95	0.61			10.64	0.59	49		0.5	+10.2							21.0
1	DH 75 107																																			
2		19.10	35.02	5.83	1.05	61.80	0.00	2.68	1.00	50.00	2.33	1.1	63.4	1.21	2.27	0.37	0.07			6.73	0.88			6.36	0.48	26		5.4	+1.4							24.0
3		1.15	1.00	36.00	0.65	38.80	0.40	7.12	0.00	28.10	0.07	34	101.4	0.12	0.10	3.65	0.07			11.63	0.88			7.98	0.81	31		0.4	+9.2							28.7
4		0.13	0.09	14.52	0.23	14.84	0.96	7.80	0.18	4.80	0.08	14	97.9	0.02	0.01	1.42	0.02			13.57	0.94			12.15	0.42	28		0.2	+12							47.2
5		0.11	0.09	13.00	0.18	13.38	0.80	6.64	0.10	4.40	0.06	41	78.8	0.01	0.01	1.02	0.01			8.85	0.49			7.83	0.48	41		0.3	+8.1							19.1
1	DH 75 [illegible]																																			
2		15.81	22.07	30.17	0.81	68.84	0.00	2.12	0.76	64.00	0.04	22	46.6	1.05	1.47	2.01	0.05			3.95	0.60			1.94	0.55	[illegible]		3.1	-0.7							
3																																				
4		3.79	4.43	11.61	0.80	20.03	0.00	5.72	0.04	13.30	0.04	4.4	54.7	0.21	0.24	0.64	0.04			1.56	0.44			0.92	0.40	47		0.8	+0.4							
5		0.49	0.45	20.35	0.47	21.76	0.64	7.68	0.06	11.75	0.07	30.	92.8	0.05	0.04	1.89	0.04			7.21	0.77			5.32	0.73	16		0.4	+5.6							
6		0.27	0.27	18.39	0.32	19.25	0.80	7.53	0.30	9.10	0.10	35	98.9	0.03	0.03	1.82	0.03			10.63	0.84			8.01	0.81	50		0.5								
7		0.16	0.18	17.57	0.24	18.15	1.04	9.40	0.16	6.00	0.09	43	87.1	0.01	0.02	1.53	0.02			2.21	0.43			2.28	0.41	[illegible]		0.2								

Table 34 Suitability of Bedrock Material for Use as Plant Media for Revegetation - Horse Nose Butte Area, Montana

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
101-1	0-5	Soil	Suitable	
101-2	5-10.0	Sh)		
	10.0-13.4	Lignite)		
	13.4-15.0	Sish)	Unsuitable	Clay-instability
101-3	15.0-31.7	Ss	Limited Suitability	Acidity
101-	31.7-33.1	Sh	Unsuitable	Clay-instability
101-	33.1-41.1	Coal	Unsuitable	
101-4	41.1-70.2	SiSt Ss Sh	Unsuitable	Sodium-instability
	70.2-70.9	Coal	Unsuitable	
101-5	70.9-82.7	SiSt Css	Unsuitable	Clay-instability
	82.7-85.4	SiSh	Unsuitable	Instability-clay layers
	85.4-87.3	Coal	Unsuitable	
101-6	87.3-146.2	SiSt Ss Sh	Unsuitable	Sodium-instability
	146.2-176.8	Sh Coal	Unsuitable	
101-7	176.8-193.6	Sh	Unsuitable	Clay-instability
101-8	193.6-202.5	SiSs	Unsuitable	Clay-instability
101-9	202.5-212.1	SiSh	Unsuitable	Sodium-instability
	212.1-215.5	Coal	Unsuitable	
	215.5-218.6	SiSh	Unsuitable	Sodic-instability

Sh - shale
CbSh - carbonaceous shale
Ss - sandstone
SiSt - Siltstone
Cec - Cation exchange capacity
SiSh - silty shale
Sst - sandy siltstone
SiSs - silty sandstone
Css - clayey sandstone
C Sist - clayey siltstone
S Sist - sandy siltstone
/ - with
BR - baked rock

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
102-1	0-5.2	Soil	Suitable	
102-2	5.2-25.0	Ss	Suitable	
	25.0-27.6	Coal	Unsuitable	
	27.6-30.3	Sh SiSt	Unsuitable	Instability-clay
102-3	30.3-44.8	Ss	Limited suitability	Acidity-instability
	44.8-53.7	Coal	Unsuitable	
102-4	53.7-69.6		Limited suitability	Thin clay layers
102-5	69.6-85.6		Limited suitability	Sodium-instability
102-6	85.6-101.3	S Sist Ss	Suitable	Low Cec
	101.3-104.9	Coal	Unsuitable	
102-7	104.9-137.4	Sh	Unsuitable	Sodium-instability
102-8	137.4-161.6	SiSs S Sist SiSh	Unsuitable	Sodium-instability
	161.6-178.2	Coal CbSh	Unsuitable	
102-9	178.2-201.7		Unsuitable	Clay - sodium
102-10	201.7-208.7		Unsuitable	Cementation-sodium

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
103-1	0-5.0	Soil	Suitable	
103-2	5.0-21.7	Ss	Suitable	Low Cec
	21.7-25.0	SiSh	Suitable	
		Coal		
		CbSh		
103-3	25.0-47.7	Ss	Suitable	Acidity
103-4	47.7-55.4	SiSh	Limited suitability	Clay
	55.4-65.2	Coal	Unsuitable	
103-5	65.2-75.9	SiSh	Unsuitable	Sodium-clay layers
		SiSs		
103-6	75.9-87.0	SiSs	Unsuitable	Sodium-instability-clay
103-7	87.0-106.4	SiSh	Unsuitable	Clay-sodium instability
		SiSt	Unsuitable	Clay-sodium-instability
	106.4-108.2	Coal	Unsuitable	
103-8	108.2-123.7	SiSh	Unsuitable	Clay layers-Sodium-instability
		SiSt		
103-9	123.7-150.4	Ss	Unsuitable	Instability-sodium
	150.4-154.7	Coal	Unsuitable	
103-10	154.7-169.6	Sh	Unsuitable	Clay-instability-sodium
	169.6-185.1	Coal	Unsuitable	
103-11	185.1-202.8	Sh	Unsuitable	CbSh-clay sodium
		SiSt		

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
104-1	0-16.5	Soil	Suitable	
104-2	16.5-31.1	Soil	Limited Suitability	Perm-clay
	31.1-35.5	Boulder	Unsuitable	Hard limestone
	35.5-36.8	Boulder	Unsuitable	Hard granite
104-3	36.8-46.5	Soil	Suitable	Gravel
	46.5-50.0	Coal	Unsuitable	
104-4	50.0-80.8	SiSh	Unsuitable	Clay-sodium Instability
		C Sist		
	80.8-99.4	Coal	Unsuitable	
104-5	99.4-114.0	SiSh	Unsuitable	Clay-sodium Instability
104-6	114.0-118.4	SiSs S Sist	Unsuitable	Sodium-instability
104-7	118.4-123.5	SiSh	Unsuitable	Sodium-instability
104-8	123.5-133.5	Ss	Unsuitable	Sodium-instability

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
105-1	0-12.4	Soil	Suitable	
105-2	12.4-31.8	Soil	Suitable	
	31.8-33.8	SiSs	Suitable	
105-3	33.8-54.9	C Sist SiSh	Suitable	
	54.9-56.8	Coal	Unsuitable	
105-4	56.8-70.1	Sh SiSs C Sist	Limited Suitability	Clay-sodium
	70.1-76.5	Coal	Unsuitable	
	76.5-77.3	CbSh	Unsuitable	Clay-perm
105-5	77.3-80.9	Sh	Unsuitable	Clay-instability-sodium
	80.9-102.5	Coal	Unsuitable	
	102.5-103.5	SiSt	Unsuitable	Carbonaceous-perm
105-6	103.5-133.6	Sh/Coal	Unsuitable	Clay-indurated-sodium

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
	0-2.0	Soil	Suitable	Erosive
106-1	2.0-22.3	Ss	Limited Suitability	Acidity-clay layers
	22.3-22.7	Coal	Unsuitable	
106-2	22.7-34.6	C Sist	Suitable	
106-3	34.6-44.9	SiSt	Suitable	
	44.9-55.3	Coal	Unsuitable	
	55.3-57.3	Sh	Unsuitable	Indurated - clay - perm
106-4	57.3-75.7	Ss	Suitable	
	75.7-78.2	SiSt) Coal) SiSt)	Unsuitable	Thin bedded
106-5	78.2-81.3	Sh) SiSh)	Limited suitability	Instability-clay
	81.3-82.2		Unsuitable	Hard limestone
106-6	82.2-98.3	Ss	Unsuitable	Sodium-instability
106-7	98.3-121.6	SiSh) Ss)	Unsuitable	Sodium - clay
	121.6-125.1	Coal	Unsuitable	
	125.1-128.6	SiSh	Unsuitable	Indurated - carbon-aceous clay
		CbSh		
	128.6-150.7	Coal	Unsuitable	
106-9	150.7-165.3	SiSh	Unsuitable	Indurated-clayey-sodium
106-10	165.3-180.5		Unsuitable	Sodium-instability

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
	0-0.7	Soil	Limited	Amount-erosiveness
107-1	0.7-11.8	C Sist	Limited	Lime-perm
	11.8-28.5	Sh	Unsuitable	Clayey-perm
		C Sh		
107-2	28.5-35.3	SiSt	Limited	Instability
		S Sist		
	35.3-37.6	Sh	Unsuitable	Clay-instability
	37.6-45.4	Coal	Unsuitable	
107-3	45.4-56.0	Sh	Unsuitable	Clayey-indurated-sodic
	56.0-73.8	Coal	Unsuitable	
107-4	73.8-93.8	Sh	Unsuitable	Instability-sodium
107-5	93.8-103.8		Unsuitable	Instability-sodium

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
108-1	0-8.0	Soil	Suitable	
108-2	8.0-20.3	SiSh	Limited	Clayey-instability
	20.3-21.7	Coal	Unsuitable	
	21.7-23.0	SiSh	Unsuitable	Clayey-carbonaceous
108-3	23.0-26.0	SiSh	Limited	Perm-clayey
108-4	26.0-34.1	Ss	Limited	Perm-instability
	34.1-43.3	Coal	Unsuitable	
108-5	43.3-58.4	Sh	Unsuitable	Clayey-sodium
	58.4-76.2	Coal	Unsuitable	
108-6	76.2-98.0	SiSh	Unsuitable	Clayey-sodium-instability
108-7	98.0-103.5	SiSs	Unsuitable	Sodium-instability

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
	0-3	Soil	Suitable	
109-1	3-21.5	C Sist	Suitable	Lime - salts
109-2	21.5-24.0	Ss	Suitable	Low Cec
109-3	24.1-38.6	SiSh SiSt	Suitable	Clayey-layers
109-4	38.6-98.7	SiSt	Suitable	
109-5	98.7-105.2	Sh/Ss	Limited	Amount-clayey layers-
	105.2-108.2	Ss	Limited	Depth
	108.2-111.7	Sh CbSh	Unsuitable	Clayey-instability
	111.7-128.5	Coal	Unsuitable	
109-6	128.5-140.8	SiSh	Unsuitable	Sodium-clayey
109-7	140.8-161.0	SiSt Ss	Unsuitable	Sodium-instability

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
	0-0.5	Soil	Suitable	
110-1	.5-47.8	SiSs	Suitable	Low Cec
	47.8-67.5	Sh	Unsuitable	Clayey
110-2	67.5-70.6	Sh	Limited	Amount-clay - depth
	70.6-72.3	Coal	Unsuitable	
	72.3-78.7	ShSs	Limited	Clayey-layers

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
	0-2.4	Soil	Suitable	
111-1	2.4-6.8	C Sist	Suitable	Lime-indurated
111-2	6.8-53.2	Ss	Suitable	Low Cec
	53.2-56.0	Css	Limited	Clayey-instability
	56.0-60.9	Ss	Suitable	Amount - depth -
111-3	60.9-66.5	SiSh	Limited	Clayey
	66.5-83.6	Coal	Unsuitable	
111-4	83.6-90.0	Sh	Limited	Amount - depth - clayey
		Coal		
		Sh		

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
	0-1.3	Soil	Unsuitable	Nonuniform depth
113-1	1.3-7.5	C Sist	Unsuitable	Clayey-slainity
113-2	7.5-29.0	SiSh	Unsuitable	Clayey-sodium
	29.0-48.8	Coal	Unsuitable	
113-3	48.8-63.4	Sh	Unsuitable	Clayey-sodic
113-4	63.4-71.1	SiSt	Unsuitable	Sodic-instability
113-5	76.5-81.6	Sh	Unsuitable	Clayey-sodic

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
	0-1.5	Soil	Suitable	
114-1	1.5-41.8	SiSs	Suitable	Caliche - clay layers
114-2	41.8-59.7	SiSh	Unsuitable	Sodic - clayey
	59.7-79.8	Coal	Unsuitable	
114-3	79.8-97.2	Sh	Unsuitable	Clayey- sodium
114-4	97.2-107.5	ShSs Ss	Unsuitable	Sodium-instability

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
116-1	0-5.0	Soil	Suitable	
116-2	5.0-27.0	Soil	Limited	Clayey-lime
	27.0-37.2	Coal	Unsuitable	
116-3	37.2-49.0	SiSh	Unsuitable	Clayey - instability-sodic

Core No.	Depth Feet	Type	Suitability Classification	Deficiency
	0-1.4	Soil	Suitable	
117-1	1.4-10.9	SiSs	Suitable	
	10.9-27.3	Coal	Unsuitable	
117-2	27.3-34.0	Sh	Limited	Clayey-instability
	34.0-36.0	Coal	Unsuitable	
117-2	36.0-40.3		Limited	Clayey-instability

SCREENABLE SOIL CHARACTERIZATION AS RELATED TO LAND RECLAMATION

By
William B. Peters, Luvern L. Resler, and Robert Vader 1/

Soil is characterized by laboratory methods to confirm judgment in field appraisals. There is a tendency among most laboratory activities to "over test"; i.e., perform too many or unnecessary tests on certain soils at the expense of not performing essential or critical testing on particular samples. Also, laboratory activities tend to emphasize comprehensive analyses of samples from master sites and neglect selection, sequence, and quality control in mass testing performed on a screenable basis. The latter-type testing is frequently handled as routine work utilizing the least dependable personnel and considered not worthy of competent and close supervision. Thus, too often the screenable laboratory testing becomes a liability rather than an asset in supporting land classification surveys. Because the screenable testing represents coverage of areas involving a high sampling density, it serves as an extremely important input into land categorization. Therefore, it should be administered for performance with respect to both quality and quantity commensurate with the goals and objectives of the investigation.

The objective of characterizing soil and overburden will be to support judgment in estimating land reclamation potential. (Overburden refers to the material consolidated or unconsolidated overlying minable resources in relation to surface mining.) Thus, the laboratory analyses must be performed on an action program basis and serve a practical purpose. Therefore, it is essential the physical and chemical characteristics of the soil and overburden be appraised in relation to edaphology; i.e., a medium suitable for the support of plant growth, rather than pedology.

Because the laboratory studies should serve to support field appraisals, all laboratory work should be closely coordinated with fieldwork. For full effectiveness, laboratory studies must be preceded by field studies. The number and type of studies will be determined by area conditions - particularly variability, the controlling project specifications, and needs. There should be a joint plan between field and laboratory investigations prior to taking of samples if maximum utilization of data is

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to be obtained. Problems should be studied rather than standard or routine tests made [Kellogg, 1962].

In submitting soil samples for laboratory characterizations, the laboratory should be furnished with pertinent field appraisals along with the tentative land utilization and quality designation. The soil and subsoil samples should represent genetic horizons with no more than 60-cm depth per sample. Substrata samples should represent uniform overburden with no more than 200 cm per sample unless drill hole diameters preclude obtaining sufficient material for laboratory and greenhouse studies.

The first priority in laboratory characterization should be accomplished by direct and indirect measurements for evaluating soil structure and its stability, soil-cation-exchange capacity or surface area, and soil reaction. After this is accomplished, then consideration should be given to testing that confirms, explains the causes of phenomena previously observed or predicted, reveals the presence of toxic elements (salinity level, boron content, alkali, acidity, reduction products, etc.), and indicates what and how much is required to cope with the soil deficiency under eventual field conditions and the moisture regimen expected to prevail [Peters, 1965].

Based on present knowledge of the area, the support characterizations should include field measurements for water movement and retention in soil and laboratory determinations for structure stability [Gardner, 1945] through measurements of floc volume and hydraulic conductivity of fragmented samples; moisture retentivity at 15-bars pressure; soil reaction by measurement of pH in water and neutral salt solution; soil salinity by measurement of specific electrical conductance of soil-water extracts; soil solution concentration and composition including sodium and calcium plus magnesium; cation exchange capacity; exchangeable cation status; residual gypsum; gypsum requirement; acid soluble carbonates; and others.

Samples collected in a reduced state may be alkaline or neutral while reduced, but acid when oxidized. Therefore, we should be on the "lookout" for such conditions and characteristics and assure reduced material is also analyzed in an aerated condition. Samples exhibiting acidity upon oxidation should be further analyzed to ascertain reduction products associated with the observed phenomenon.

Should conventional acidity; i.e., other than oxidation product, be encountered, the testing will be expanded to include acidity by measurement of neutral salt exchange acidity including aluminum, titratable acidity (amount of acidity neutralized at a selected pH), and soluble aluminum.

In screenable testing, the characterization for moisture retentivity at pressures less than 15 bars is not recommended unless a suitable use can be established. Measurements of moisture retentivity at 15-bars pressure are recommended because water content at this potential is usually correlated with several characteristics including amount and kind of clay, surface area, and cation exchange capacity. Moisture percentages at this potential would probably not be applicable in simulating water content at wilting for native vegetation.

In initial screening, diluted soil-water suspensions may be substituted for the time-consuming, saturated soil extracts in measuring electrical conductance provided limitations are ascertained. The reliability of higher moisture contents even as a tool in screening depends on the kind of salts present. For chloride salts, the results will be only slightly affected by the moisture content, but if sulfate or carbonate salts, which have relatively low solubility, are present in appreciable quantities, the apparent amount of soluble salt will depend on the soil-water ratio [Richards, 1954].

We do not concur in the practice of characterizing vast numbers of samples for textural class through measurements of particle-size distribution. This blanket laboratory analysis for soil textural class is neither required nor desired. Particle-size analysis should be limited to master site characterization, the occasional confirmation of field textural appraisals, and the training of new employees.

In the screenable characterization of samples, a procedure for the sequence of testing and screening of samples should encompass the following phases. Under Phase I of the scheme, all samples would be characterized for (1) soil structure stability through measurement of hydraulic conductivity on a fragmented sample basis during the 6th and 24th hours and volume of wet settled floccules, (2) moisture retentivity at 15-bars pressure, (3) electrical conductivity of soil-water extract, and (4) pH in water and in 0.01 molar calcium chloride solution.

In the second phase, <u>selected</u> samples suspected through the testing results of Phase 1 to be salt affected should be characterized for electrical conductivity of the saturation extract and sodium adsorption ratio.

In the third phase, <u>selected</u> samples suspected through the testing results of Phases I and II to be salt affected with respect to sodium will be tested for either gypsum requirement or residual gypsum, depending on salinity levels and associated pH values. Residual gypsum will be estimated by measuring calcium plus magnesium in a 1:5 soil-water ratio extract and reported in milliequivalents per 100 grams.

In the fourth phase, selected samples suspected through testing results of Phase I to be highly acid and low in base saturation and nonsaline should be further characterized for bases specifically sodium and calcium plus magnesium and acidity including the aluminum component extractable with a neutral salt; i.e., 1.0N potassium chloride. This will enable computation of effective soil-cation-exchange capacity; i.e., CEC at soil pH and the exchangeable aluminum percentage of this CEC.

In the fifth phase, selected samples having been characterized during Phases I, II, and IV to be saline acid would be characterized for soluble aluminum.

The above-described characterization program would not preclude testing on a "complete analysis" basis on samples from master sites.

LABORATORY ANALYSES AND PROCEDURES

Moisture Retention was determined by ceramic plates (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 29, 30 and 31:109-110).

Particle-Size Analyses were determined by pipeting analysis (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 41:122-124).

Disturbed Hydraulic Conductivity was determined by the use of plastic tubes (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 34b:112-113).

pH of 1:15 Soil Suspension (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 21b:102), (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 60-3,4:922-923) and (Bear, et al., Chemical of Soils, 1964).

pH Reading in $CACl_2$ Solution (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 60-3.5:923).

Saturation Extract taken from saturation soil paste using Bariod filter press and measuring soluble salts by use of electrode conductivity bridge (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 2 and 3:84-88, 27:107 and 4:89-90), C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 62-1:933-988) and (Bear, et al., Chemical of Soils, 1964).

Carbonates and bicarbonates were determined by acid titration and chlorides were determined by the Mohr volumetric method (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 82:145-146 and 84:146), C. A. Black, et al.,

Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 62-3.4.1:945-947 and 62-3.5.1:947-948), (M. J. Taras, et al., Standard Methods for the Examination of Water and Wasteway, Thirteenth Edition, for carbonate and bicarbonate only 102:52-56), (Bear, et al., Chemical of Soils, 1964), and (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter A1, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory analysis for chloride only, p. 69).

Sodium, Potassium, Calcium and Magnesium were determined by atomic absorption (Perkin-Elmer, Analytical Method for Atomic Absorption

Spectrophotometry, 1973) and Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter A1, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory Analysis, 66, 109, 133 and 143).

Nitrate was determined by phenoldsulfonic acid (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 15:100), (C. A. Black, et al., Methods of Soil Analysis Part 2, Agronomy No. 9, American Society of Agronomy 84-5.3:1216-1219) and (M. J. Taras, et al., Standard Methods for the Examination of Water and Wasteway, Thirteenth Edition, 133:233-237).

Exchangeable Sodium and Potassium were extracted by ammonium acetate solution. Cation-Exchange Capacity was extracted by ammonium acetate and sodium acetate (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 18:100-101 and 19:101) and (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 72-3:1033, 72-3.2.1:1033-1034 and 57-1:891-895).

Exchangeable Sodium Percentage was determined by calculation (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 20a:101).

Gypsum determined by increase in soluble calcium plus magnesium content upon dilution (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 22c:104).

Gypsum Requirement (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agricultural Handbook No. 60, 22d:104-105).

Boron was determined by extracting with hot water (Bear, et al., Chemical of Soils, 490-494) and (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 75-4:1062-1063).

Trace Metals were determined by atomic absorption either by flame or graphite furnace (Perkin-Elmer, Analytical Method for Atomic Absorption Spectrophotometry, 1973), Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter A1, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases, Book 5 - Laboratory Analysis, 50-157) and (M. J. Taras, et al., Standard Methods for the Examination of Water and Wasteway, Thirteenth Edition).

Organic Carbon - The Walkley-Block method is used, and diphenylamine is the indicator. (Methods of Soil Analysis, Part 2, Agronomy No. 9 American Society of Agronomy 90-3:1372-1375).

Bulk Density - Clod method. Density measured by water displacement. (Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 30-4:381-383).

In addition to the foregoing testing program, greenhouse pot studies were made on selected samples to indicate possible toxic or other unfavorable conditions for plant growth. With the procedures used in the greenhouse studies, the results do not reflect adverse physical conditions or nitrogen and phosphorous deficiencies.

GLOSSARY

Annual Plant (annuals), A plant that completes its life cycle and dies in 1 year or less.

Aspect, The direction toward which a slope faces. Exposure.

Available Nutrient, The part of the supply of a plant nutrient in the soil that can be taken up by plants at rates and in amounts significant to plant growth.

Available Water, The part of the water in the soil that can be taken up by plants at rates significant to their growth. Usable: obtainable.

Bedrock, Any part of the consolidated geologic formation, soft, weathered or hard that has remained in place and is relatively unchanged.

Broadcast Seeding, Scattering seed on the surface of the soil. Contrast with drill seeding which places the seed in rows in the soil.

Buffer, Substances in soil or water that act chemically to resist changes in reaction or pH.

Calcareous Soil, Soil containing sufficient calcium carbonate (often with magnesium carbonate) to effervesce visibly when treated with cold 0.1 normal hydrochloric acid.

Capillary Water, The water held in the "capillary" or small pores of a soil, usually with tension greater than 60 centimeters of water. Much of this water is considered to be readily available to plants.

CFS, Cubic feet per second - measurement of water flow.

Channel Stabilization, Erosion prevention and stabilization of velocity distribution in a channel, using jetties, drops, revetments, vegetation, and other measures.

Clay (soils) (1) A mineral soil separate consisting of particles less than 0.002 millimeter diameter. (2) A soil textural class. (3) (engineering) A fine-grained soil that has a high plasticity index in relation to the liquid limits.

Compaction, The closing of the pore spaces among the particles of soil and rock, generally caused by running heavy equipment over the area, as in the process of leveling the overburden material of strip mine banks.

Companion Crop (See Nurse Crop)

Conifer, A tree belonging to the order Coniferae, usually evergreen with cones and needle-shaped or scale-like leaves and producing wood known commercially as "softwood."

Contour, An imaginary line connecting points of equal height above sea level as they follow the relief of the terrain.

Cool-Season Plant, A plant that makes its major growth during the cool portion of the year, primarily in the spring but in some localities in the winter.

Deciduous, Refers to a tree that sheds all its leaves every year at a certain season.

Deep Chiseling, Deep chiseling is a surface treatment that loosens compacted spoils. The process creates a series of parallel slots on the contour in the spoils surface which impedes water flows and markedly increases infiltration.

Density, Forage, The percent of ground surface which appears to be completely covered by vegetation when viewed directly from above.

Density, Stand, Density of stocking expressed in number of trees per acre.

Broadcast Seeding, A method of establishing a stand of vegetation by sowing seed on the ground surface.

Dissolved Solids, The difference between the total and suspended solids in water.

Disturbed Land, Land on which excavation has occurred or upon which overburden has been deposited, or both.

Dozer or Bulldozer, Tractor with a stell plate or blade mounted on the front end in such a manner that it can be used to cut into earth or other material and move said material primarily forward by pushing.

Ecology, The science that deals with the mutual relation of plants and animals to one another and to their environment.

Ecosystem, A total organic community in a defined area or time frame.

Effective Precipitation, That portion of total precipitation that becomes available for plant growth. It does not include precipitation lost to deep percolation below the root zone or to surface runoff.

Effluent, Any water flowing out of the ground or from an enclosure to the surface flow network.

Environment, All external conditions that may act upon an organism or soil to influence its development, including sunlight, temperature, moisture and other organisms.

Erodibility, The relative ease with which one soil erodes under specified conditions of slope as compared with other soils under the same conditions; this applies to both sheet and gully erosion.

Erosion, The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. Detachment and movement of soil or rock fragments by water, wind or ice, or gravity.

Essential Element (plant nutrition), A chemical element required for the normal growth of plants.

Evapotranspiration, A collective term meaning the loss of water to the atmosphere from both evaporation and transpiration by vegetation.

Excavation, The act of removing overburden material.

Fertilizer, Any natural or manufactured material added to the soil in order to supply one or more plant nutrients.

Fertilizer Grade, The guaranteed minimum analysis in whole numbers, in percent, of the major plant nutrient elements contained in a fertilizer material or in a mixed fertilizer. For example, a fertilizer with a grade of 20-10-5 contains 20 percent nitrogen (N), 10 percent available phosphoric acid (P_2O_5), and 5 percent water-soluble potash (K_2O). Minor elements may also be included. Recent trends are to express the percentages in terms of the elemental fertilizer (nitrogen (N), phosphorous (P), and potassium (K)).

Fill, Depth to which material is to be placed (filled) to bring the surface to a predetermined grade. Also, the material itself.

Forage, Unharvested plant material which can be used as feed by domestic animals. Forage may be grazed or cut for hay.

Forest Land, Land bearing a stand of trees at any age or stature, including seedlings and of species attaining a minimum of 6 feet average height at maturity or land from which such a stand has been removed but on which no other use has been substituted. The term is commonly limited to land not in farms; forests on farms are commonly called woodland or farm forests.

Germination, Sprouting; beginning of growth.

Gradation, A term used to describe the series of sizes into which a soil sample can be divided.

Grain Size, Physical size of soil particle, usually determined by either sieve or hydrometer analysis.

Ground Cover, Any living or dead vegetative material producing a protecting mat on or just above the soil surface.

Ground Water, Subsurface water occupying the saturation zone, from which wells and springs are fed. In a strict sense the term applies only to water below the water table. Also called plerotic water; phreatic water.

Growing Season, Determined by the Lowery-Johnson Method.

Gully Erosion, Removal of soil by running water, with formation of deep channels that cannot be smoothed out completely by normal cultivation.

Hydroseeding, Dissemination of seed hydraulically in a water medium. Mulch, lime, and fertilizer can be incorporated into the sprayed mixture.

Impervious, Prohibits fluid flow.

Infiltration, Water entering the ground water system through the land surface.

Intermittent Stream, A stream or portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and is dry for a large part of the year.

Land Classification, Classification of specific bodies of land according to their characteristics or to their capabilities for use. A use capability classification may be defined as one based on both physical and economic considerations according to their capabilities for man's use, with sufficient detail of categorical definition and cartographic (mapping) expression to indicate those differences significant to men.

Land Use Planning, The development of plans for the uses of land that, over long periods, will best serve the general welfare, together with the formulation of ways and means for achieving such uses.

Leaching, The removal of materials in solution by the passage of water through soil.

Leachate, Liquid that has percolated through a medium and has extracted dissolved or suspended materials from it.

Legume, A member of the legume or pulse family, leguminosae. One of the most important and widely distributed plant families. Includes many valuable food and forage species, such as the peas, beans, peanuts, clovers, alfalfas, sweet clovers, lespedezas, vetches and kudzu. Practically all legumes are nitrogen-fixing plants.

Lime, Lime, from from the strictly chemical standpoint, refers to only one compound, calcium oxide (CaO); however, the term lime is commonly used in agriculture to include a great variety of materials which are usually composed of the oxide, hydroxide, or carbonate of calcium or of calcium and magnesium. The most commonly used forms of agricultural line are ground limestone, marl, and oyster shells (carbonates), hydrated lime (hydroxides), and burnt lime (oxides).

Quicklime	- limestone + heat (calcined) CaO
Hydrated lime	- quicklime + H_2O $Ca(OH)_2$
Slaked lime	- same as hydrated but slaking equipment is used for adding water
Milk of lime	- water mixture containing lime in solution + lime in suspension

Micro-Climate, A local climatic condition near the ground resulting from modification of relief, exposure, or cover.

Micro-Nutrients, Nutrients in only small, trace, or minute amounts.

Mined-Land, Land with new surface characteristics due to the removal of mineable commodity by surface mining methods and subsequent surface reclamation.

Mulch, A natural or artificial layer of plant residue or other materials placed on the soil surface to protect seeds, to prevent blowing, to retain soil moisture, to curtail erosion, and to modify soil temperature.

Natural Revegetation, Natural reestablishment of plants; propagation of new plants over an area by natural processes.

Natural Seeding (Volunteer), Natural distribution of seed over an area.

Neutralization, The process of adding an acid or alkaline material to water or soil to adjust its pH to a neutral position.

Neutral Soil, A soil in which the surface layer, at least to normal plow depth, is neither acid nor alkaline in reaction. For most practical purposes, soil with a pH ranging from 6.6 through 7.3.

Nitrogen Fixation, The conversion of atmospheric (free) nitrogen to nitrogen compounds. In soils the assimilation of free nitrogen from the air by soil organisms (making the nitrogen eventually available to plants). Nitrogen fixing organisms associated with plants such as the legumes are called symbiotic; those not definitely associated with plants are called nonsymbiotic.

Nurse Crop, A planting or seeding that is used to protect a tender species during its early life. A nurse crop is usually temporary and gives way to the permanent crop. Sometimes referred to as a companion crop.

Nutrients, Any element taken into a plant that is essential to its growth.

Overburden, The earth, rock, and other materials which lie above the coal.

Percolation, Downward movement of water through soils.

Permeability, The measure of the capacity for transmitting a fluid through the substance. In this report the substance is overburden (soil and bedrock).

pH, The symbol or term refers to a scale commonly used to express the degrees of acidity or alkalinity. On this scale pH of 1 is the strongest acid, pH of 14 is the strongest alkali, pH of 7 is the point of neutrality at which there is neither acidity or alkalinity. pH is not a measure of the weight of acid or alkali contained in or available in a given volume.

Pollution, Environmental degradation resulting from man's activities or natural events.

Pond, A body of water of limited size either naturally or artificially confined and usually smaller than a lake.

Rain (1) Heavy--Rain which is falling at the time of observation with an intensity in excess of 0.30 in. per hr (over 0.03 inch in 6 min). (2) Light--Rain which is falling at the time of observation with an intensity of between a trace and 0.10 in. per hr (0.01 inch in 6 min). (3) Moderate--Rain which is falling at the time of observation with an intensity of between 0.11 in. per hr (0.01+ inch in 6 min) and 0.30 in. per hr (0.03 inch in 6 min).

Range Land, The natural vegetation is predominantly grasses, grasslike plants, forbs, or shrubs.

Percolation Rate, Usually expressed as a velocity, at which water moves through saturated granular material. The term is also applied to quantity per unit or time of such movement, and has been used erroneously to designate infiltration rate or infiltration capacity.

Reclamation, The process of reconverting mined land to its former or other productive uses.

Reconstructed Profile, The result of selective placement of suitable overburden material on reshaped spoils.

Recreation Land, Land and water used, or usable primarily as sites for outdoor recreation facilities and activities.

Reforestation, The natural or artificial restocking of an area with forest trees.

Regrading, The movement of earth over a depression to change the shape of the land surface. A finer form of backfilling.

Rehabilitation, Implies that the land will be returned to a form and productivity in conformity with a prior land use plan, including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values.

Revegetation, Plants or growth which replaces original ground cover following land disturbance.

Ripping, The act of breaking, with a tractor-drawn ripper or long angled steel tooth, compacted soils or rock into pieces small enough to be economically excavated or moved by other equipment as a scraper or dozer.

Runoff, That portion of the rainfall that is not absorbed by the deep strata: is utilized by vegetation or lost by evaporation or may find its way into streams as surface flow.

Saline-Sodic Soil, A soil having a combination of a harmful quantity of salts and either a high degree of sodicity or a high amount of exchangeable sodium, or both, so distributed in the soil profile that the growth of most crop plants is less than normal.

Saline Soil, A soil containing enough soluble salts to impair its productivity for plants but not containing an excess of exchangeable sodium.

Sandstone, A cemented or otherwise compacted detrital sediment composed predominantly of quartz grains, the grades of the latter being those of sand.

Saturation, Completely filled; a condition reached by a material, whether it be in solid, gaseous, or liquid state, which holds another material within itself in a given state in an amount such that no more of such material can be held within it in the same state. The material is then said to be saturated or in a condition of saturation.

Sediment, Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

Sediment Basin, A reservoir for the confinement and retention of silt, gravel, rock, or other debris from a sediment-producing area.

Seedbed, The soil prepared by natural or artificial means to promote the germination of seed and the growth of seedlings.

Seep, A more or less poorly defined area where water oozes from the earth in small quantities.

Shale, Sedimentary or stratified rock structure generally formed by the consolidation of clay or clay-like material.

Silt, Small mineral soil grains the particles of which range in diameter from 0.05 to 0.002 mm (or 0.02-0.002 mm in the international system).

Soil (See Acid Soil and Alkaline Soil), Surface layer of the earth, ranging in thickness from a few inches to several feet composed of finely divided rock debris mixed with decomposing vegetative and animal matter which is capable of supporting plant growth.

Soil Conserving Crops, Crops that prevent or retard erosion and maintain or replenish rather than deplete soil organic matter.

Soil Porosity, The degree to which the soil mass is permeated with pores or cavities. It is expressed as the percentage of the whole volume of the soil which is unoccupied by solid particles.

Soil Profile, A vertical section of the soil through all its horizons and extending into the parent material.

Soil Structure, The combination or arrangement of primary soil particles into secondary particles, units, or beds.

Solum, The upper part of a soil profile, above the parent material, in which the processes of soil formation are active. The solum in mature soils includes the A and B horizons. Usually the characteristics of the material in these horizons are quite unlike those of the underlying parent material. The living roots and other plant life and animal life characteristic of the soil are largely confined to the solum.

Spoil, The overburden or non-coal material removed in gaining access to the coal or mineral material in surface mining.

Spoil Bank (Spoil Pile), Area created by the deposited spoil or overburden material prior to backfilling. Also called cast overburden.

Stratified, Composed of, or arranged in, strata or layers, as stratified alluvium. The term is applied to geological materials. Those layers in soils that are produced by the processes of soil formation are called horizons, while those inherited from parent material are called strata.

Strip, To mine a deposit by first taking off the overlying burden.

Strip Mine, Refers to a procedure of mining which entails the complete removal of all material from over the product to be mined in a series of rows or strips; also referred to as "open cut," "open pit," or "surface mine."

Strip Mining (See Surface Mining)

Stripping, The removal of earth or non-ore rock materials as required to gain access to the ore or mineral materials wanted. The process of removing overburden or waste material in a surface mining operation.

Subsoil, The B horizon of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below the plowed soil (or its equivalent of surface soil) in which roots normally grow. Although a common term, it cannot be defined accurately. It has been carried over from early days when "soil" was conceived only as the plowed soil and that under it as "subsoil."

Substratum, Alluvial, colluvial and bedrock material that lies below the soil profile.

Surface Soil, That part of the upper soil of arable soils commonly stirred by tillage implements or an equivalent depth (5 to 8 inches) in non-arable soils.

Suspended Solids, Sediment which is in suspension in water but which will physically settle out under quiescent conditions (as differentiated from dissolved material).

Terrace, Sloping ground cut into a succession of benches and steep inclines for purposes of cultivation or to control surface runoff and minimize soil erosion.

Terraced Slope, A slope that is intersected by one or more terraces.

Texture, The character, arrangement and mode of aggregation of particles which make up the earth's surface.

Topdressing Material, Material that is well suited for plant media. Desired characteristics include: fertile, good tilth, permeable, contains organic matter, nonsaline, nonsodic and has water stable aggregates.

Tilth, The physical condition of a soil in respect to its fitness for the growth of a specified plant.

Topography, The shape of the ground surface, such as hills, mountains or plains. Steep topography indicates steep slopes or hilly land; flat topography indicates flat land with minor undulations and gentle slopes.

Toxic Spoil (See also Acid Spoil), Includes acid spoil with pH below 4.0. Also refers to spoil having amounts of minerals such as aluminum, manganese, and iron that adversely affect plant growth.

Transpiration, The normal loss of water vapor to the atmosphere from plants.

Unconsolidated (soil material), Soil material in a form of loose aggregation.

Vegetation, General term including grasses, legumes, shrubs, trees naturally occurring and planted intentionally.

Vegetative Cover, The entire vegetative canopy on an area.

Volunteer, Springing up spontaneously or without being planted; a volunteer plant.

Weathering, The group of processes, such as chemical action of air and rainwater and of plants and bacteria and the mechanical action of changes in temperature, whereby rocks, on exposure to the weather, change in character, decay, and finally crumble.

Wildlife, Undomesticated vertebrate animals, except fish, considered collectively.

APPENDIX F

GREENHOUSE

Table 37 Horse Nose Butte Greenhouse Data.

Sample No.	Depth (ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge		Germination: Number of Seeds Germinated		Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm)		Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm)		Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
			I	II	I	II			I	II		I	II			
75-101- 3	15.0 - 31.7	2	8	8	31	32	2	1	2.00	2.76	60	29	28	0	0	36.9
75-101 -4	41.1 - 70.2	2	8	8	38	31	1	1	2.86	3.37	78	32	25	0	1	36.4
75-101- 5	70.9 - 82.7	2	8	8	36	40	2	1	2.56	2.72	66	34	24	0	2	35.1
75-101- 6	87.3 - 143.2	2	7	7	34	38	1	1	2.69	2.85	69	32	24	0	2	41.7
75-101- 7	176.8 - 193.6	2	8	8	30	20	1	1	2.01	2.77	60	31	24	0	1	43.8
75-101- 8	193.6 - 202.5	2	8	8	39	26	0	1	2.69	2.82	69	34	29	1	3	31.2
75-101- 9	202.5 - 212.1	2	8	8	22	26	1	1	1.68	2.36	51	30	27	1	2	25.3
75-102- 2	5.2 - 25.0	2	9	9	39	38	0	0	1.58	1.63	40	28	22	1	0	11.1
75-102- 3	30.3 - 44.8	2	7	8	36	37	2	0	1.81	1.71	44	30	20	0	1	19.1
75-102- 4	57.3 - 69.6	2	9	8	35	34	0	1	1.70	1.75	43	30	18	0	3	15.0
75-102- 5	69.6 - 85.6	2	9	8	36	39	1	1	1.88	1.72	45	33	29	0	3	23.1
75-102- 6	85.6 - 101.3	2	8	8	35	39	0	0	3.31	3.18	81	36	27	0	0	17.3
75-102- 7	104.9 - 137.4	2	13	11	16	18	1	1	1.81	1.96	47	28	23	0	1	50.3
75-102- 8	137.4 - 161.2	2	7	7	34	38	1	0	3.01	3.24	78	33	26	0	1	19.8
75-102- 9	178.1 - 201.7	2	10	8	28	34	1	1	1.35	0.76	26	23	13	0	3	16.9
75-102-10	201.7 - 208.7	2	9	8	32	34	1	1	1.88	2.97	61	28	26	1	2	24.5
75-103- 2	5.0 - 21.7	2	9	9	36	37	0	0	1.98	1.97	49	29	23	1	0	11.6
75-103- 3	25.0 - 47.7	2	7	8	35	40	1	1	2.26	1.75	50	30	23	1	0	15.7

Table 37 (cont.) Horse Nose Butte Greenhouse Data.

Sample No.	Depth (ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge		Germination: Number of Seeds Germinated		Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm)		Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm)		Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
			I	II	I	II			I	II		I	II			
75-103- 4	47.7 - 55.4	2	9	9	36	36	1	1	1.21	1.30	31	25	22	0	2	20.8
75-103- 5	62.5 - 75.9	2	9	9	30	33	1	1	2.04	1.89	49	32	27	0	2	22.7
75-103- 6	75.9 - 87.0	2	8	8	34	39	0	1	2.23	2.79	63	31	27	0	1	28.9
75-103- 7	87.0 - 106.4	2	13	12	24	30	1	2	0.88	0.53	18	24	16	0	3	13.8
75-103- 8	108.2 - 123.7	2	8	9	33	32	1	1	1.93	2.02	49	32	25	0	2	40.2
75-103- 9	123.7 - 150.4	2	8	8	32	40	0	0	0.97	0.81	22	20	14	0	1	7.9
75-103-10	154.7 - 169.6	2	9	9	32	28	1	1	1.13	1.27	30	24	25	0	2	48.0
75-103-11	185.1 - 202.8	2	7	8	38	31	1	2	2.33	2.31	58	33	27	0	2	23.7
75-104- 1	0.0 - 16.5	2	10	9	38	35	1	1	2.28	2.22	56	31	25	0	1	19.7
75-104- 2	16.5 - 31.1	2	8	8	37	36	1	1	3.01	2.64	71	34	29	0	1	24.5
75-104- 4	50.0 - 80.8	2	9	9	35	29	1	2	1.57	1.80	42	27	23	0	1	19.5
75-104- 5	99.4 - 114.0	2	13	11	21	29	1	1	1.02	0.70	22	21	11	0	3	13.9
75-104- 8	123.5 - 133.5	2	7	8	34	40	0	1	3.07	3.07	77	34	29	0	1	33.7
75-105- 2	12.4 - 31.8	2	7	7	37	38	2	1	3.78	3.57	92	35	31	1	1	22.3
75-105- 3	33.8 - 54.9	2	8	8	37	36	1	1	2.40	2.40	60	32	28	2	1	23.1
75-105- 4	56.8 - 70.1	2	8	7	35	38	1	1	2.72	2.03	59	32	25	0	1	26.8

Table 37 (cont.) Horse Nose Butte Greenhouse Data.

Sample no.	Depth (ft)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	II	Germination: Number of Seeds Germinated I	II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	II	Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm) I	II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
75-106- 2	22.7 - 34.6	2	8	8	34	40	1	1	3.78	3.66	93	37	27	0	2	23.0
75-106- 3	34.6 - 44.9	2	8	7	36	36	0	1	3.09	3.65	84	37	27	0	1	19.5
75-106- 4	57.3 - 57.7	2	7	7	37	38	1	1	2.83	2.96	72	35	19	1	1	17.6
75-106- 6	82.2 - 98.3	2	8	8	34	38	0	1	2.88	2.70	70	30	27	1	2	32.7
75-106- 7	98.3 - 121.6	2	13	9	29	38	1	0	1.18	1.59	35	28	22	0	3	25.3
75-106- 9	150.7 - 165.3	2	8	8	35	34	1	0	1.50	1.56	38	27	24	0	2	40.3
75-106-10	165.3 - 180.5	2	8	9	23	38	1	0	0.95	1.07	25	24	17	0	2	13.9
75-107- 1	0.7 - 11.8	1.80	12	11	38	38	1	3	1.22	1.61	35	29	22	1	2	22.2
75-107- 2	11.8 - 37.6	2	12	9	36	33	1	3	1.35	0.92	28	26	19	1	1	18.5
75-107- 3	45.4 - 56.0	2	11	9	33	26	1	2	1.74	2.22	50	27	24	0	2	24.4
75-107- 4	73.8 - 93.8	2	8	10	36	36	1	2	1.63	1.18	35	28	21	1	2	18.5
75-107- 5	93.8 - 103.8	2	8	8	36	35	0	1	2.46	2.40	61	31	28	1	1	32.9
75-108- 2	8.0 - 20.3	2	9	9	32	30	1	3	1.52	2.10	45	27	27	0	1	26.3
75-108- 4	26.0 - 31.6	2	8	8	37	36	1	0	2.69	2.49	65	31	26	0	2	19.0
75-108- 5	31.6 - 34.1 43.3 - 58.4	2	11	12	25	30	1	1	1.64	1.97	45	27	23	0	2	21.7
75-108- 6	76.2 - 98.0	2	9	9	18	25	1	1	1.37	1.49	36	25	22	1	2	21.9
75-108- 7	98.0 - 103.5	1.95	9	8	34	35	1	2	2.49	2.83	67	34	32	0	1	33.7

Table 37 (cont.) Horse Nose Butte Greenhouse Data.

Sample No.	Depth (in)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	Germination: Days After Seeding for Ten Plants to Emerge II	Germination: Number of Seeds Germinated I	Germination: Number of Seeds Germinated II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	Harvest: Plant Dry Weight (gm) II	Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm) I	Harvest: Average Plant Height (cm) II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
R-625-32	0.0 - 12.0	2	8	8	39	35	2	0	3.22	3.33	82	33	26	0	1	17.4
R-634- 3	20.0 - 36.0	2	8	8	39	38	1	0	2.47	3.10	70	30	28	0	1	20.3
R-658-33	0.0 - 7.0	2	7	7	38	40	0	0	2.99	3.12	76	33	23	2	0	16.8
R-659-15	7.0 - 15.0	2	6	8	39	37	1	0	2.14	2.74	61	28	21	2	0	16.2
R-660-33	15.0 - 23.0	2	6	6	39	40	0	0	2.73	2.83	35	30	27	2	1	21.0
R-661-33	23.0 - 33.0	2	8	8	37	36	1	1	3.39	2.63	75	34	23	1	2	27.3
R-662-33	33.0 - 50.0	2	9	8	37	38	1	1	2.79	2.63	68	35	30	0	1	22.6
R-663-33	50.0 - 90.0	2.	9	9	36	39	1	1	1.04	1.54	32	23	20	2	2	17.4
R-664-33	90.0 - 120.0	2	9	10	33	37	1	1	0.97	1.05	25	24	17	1	2	17.4
R-665-34	0.0 - 3.0	2	6	6	36	38	1	0	3.47	3.15	83	36	26	0	0	19.2
R-666-34	3.0 - 10.0	2	8	8	33	37	2	2	1.50	1.77	41	30	21	1	2	19.1
R-667-34	10.0 - 27.0	2	10	10	36	37	1	2	1.52	1.47	37	26	23	1	3	22.2
R-668-34	29.0 - 59.0	2	11	14	28	27	2	2	1.87	1.37	41	26	20	1	2	17.0
R-669-34	59.0 - 84.0	2	11	12	33	29	1	2	0.63	0.80	18	18	12	1	3	13.9
R-670-34	84.0 - 120.0	2	12	11	31	28	1	3	1.55	1.84	42	27	24	1	2	23.5
R-671-34	0.0 - 12.0	2	7	8	37	40	1	0	2.54	2.74	66	32	20	1	1	16.5

Table 37 (cont.) Horse Nose Butte Greenhouse Data.

Sample No.	Depth (in)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge		Germination: Number of Seeds Germinated		Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm)		Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm)		Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
			I	II	I	II			I	II		I	II			
R-686-29	10.0 - 12.0	2	8	8	36	38	2	1	2.49	2.78	66	34	23	2	1	19.0
R-688-20	0.0 - 12.0	2	7	7	35	37	2	3	4.39	3.94	104	36	30	3	1	23.4
R-689-33	0.0 - 33.0	2	6	6	35	35	1	1	3.07	3.22	79	35	26	1	0	25.9
R-690-34	0.0 - 27.0	2	10	11	33	37	2	2	1.44	1.26	34	27	19	0	2	15.5
R-691-14	0.0 - 37.0	2	7	7	40	39	1	0	2.97	2.97	74	36	22	0	1	17.4
R-431-14	0.0 - 5.0	2	7	7	40	39	0	0	3.19	3.69	86	35	28	0	1	19.2
R-432-14	5.0 - 11.0	2	6	6	38	39	0	0	3.28	3.56	86	42	24	1	0	22.3
R-433-14	11.0 - 27.0	2	6	6	38	36	0	0	3.13	2.55	71	34	25	1	1	19.5
R-434-14	27.0 - 37.0	2	8	8	37	37	1	0	3.03	2.39	68	36	25	0	1	20.2
R-435-14	37.0 - 60.0	2	7	7	37	36	1	0	3.02	3.06	76	37	24	0	1	22.1
R-436-14	60.0 - 90.0	2	8	7	38	37	1	1	2.82	2.26	64	31	30	1	1	22.8
R-437-14	90.0 - 120.0	2	8	8	40	35	1	0	1.73	1.41	39	38	27	0	1	18.2
R-453-15	0.0 - 6.0	2	7	6	30	40	0	0	4.51	15.25	122	34	33	1	1	24.5
R-454-15	6.0 - 11.0	2	6	6	36	37	0	0	3.18	3.38	82	35	36	0	0	21.7
R-455-15	11.0 - 23.0	2	8	8	35	39	0	0	3.27	3.23	81	34	30	1	0	20.3
R-456-15	23.0 - 36.0	2	8	8	36	39	1	0	2.44	2.19	58	33	24	0	1	20.6
R-457-15	36.0 - 65.0	2	8	7	38	37	1	0	2.56	2.82	67	32	23	1	1	19.8
R-458-15	65.0 - 84.0	2	10	10	30	24	1	1	1.58	1.74	42	28	22	0	1	26.7

Table 37 (cont.) Horse Nose Butte Greenhouse Data.

Sample No.	Depth(in)	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge I	II	Germination: Number of Seeds Germinated I	II	Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm) I	II	Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm) I	II	Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
R-459-15	84.0 - 96.0	2	8	8	38	39	1	2	0.97	1.38	29	23	20	0	2	25.3
R-460-16	96.0 - 120.0	2	9	8	[illegible]	[illegible]	1	2	1.57	1.30	36	27	20	0	2	20.8
R-438-26	0.0 - 10.0	2	7	7	33	39	0	0	3.57	3.53	89	38	27	0	1	18.0
R-439-26	10.0 - 30.0	2	7	7	38	39	0	0	3.46	2.64	76	33	24	0	0	14.7
R-440-26	30.0 - 36.0	2	7	7	38	40	1	0	4.75	3.63	105	39	26	1	0	15.2
R-441-26	36.0 - 41.0	2	7	7	37	39	2	2	2.63	2.93	70	32	29	0	1	22.4
R-442-26	41.0 - 51.0	2	8	8	39	36	0	0	2.41	2.08	56	32	20	1	1	15.9
R-443-26	51.0 - 68.0	2	7	8	37	34	1	0	2.55	2.70	66	32	22	2	0	15.5
R-444-26	68.0 - 132.0	2	7	7	39	40	1	0	1.80	2.05	48	25	25	3	0	11.6
R-445-27	0.0 - 8.0	2	6	6	37	36	1	0	4.10	3.71	98	37	22	1	0	15.5
R-446-27	8.0 - 17.0	2	6	6	39	36	0	0	2.34	2.34	59	30	23	3	0	13.9
R-447-27	17.0 - 23.0	2	6	6	35	39	0	0	2.84	2.60	68	33	24	1	1	16.6
R-448-27	23.0 - 38.0	2	8	8	36	34	1	1	2.70	3.23	74	35	26	2	1	18.6
R-450-27	48.0 - 58.0	2	8	9	40	40	0	0	1.84	1.65	44	30	21	0	0	16.9
R-451-27	58.0 - 78.0	2	7	8	38	39	1	0	2.31	2.24	57	32	23	1	0	12.8
R-452-27	78.0 - 120.0	2	8	8	39	37	0	0	2.06	1.77	48	30	20	0	0	12.1

Table 37 (cont.) Horse Nose Butte Greenhouse Data.

Sample No.	Depth	Pot Wt. (Kg)	Germination: Days After Seeding for Ten Plants to Emerge		Germination: Number of Seeds Germinated		Salt Crust at Germination	Salt Crust at Harvest	Harvest: Plant Dry Weight (gm)		Harvest: Relative Yield (%)	Harvest: Average Plant Height (cm)		Black Leaf Tips	Soil Surface Cracks	Field Cap. (%)
			I	II	I	II			I	II		I	II			
STANDARD SOILS																
R-438-26																
Control	surface	2	7	8	35	36	0	0	2.22	2.62	61	28	21	0	1	16.1
Platner	surface	2	6	6	38	37	0	0	4.27	3.71	100	32	22	0	0	15.2
Red Rim																
Check	surface	2	7	7	37	38	0	0	3.84	4.15	100	35	25	1	0	18.4
Kimm	surface	2	6	6	35	40	0	0	4.71	4.47	115	37	38	0	0	20.6

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